9th ANNUAL INTERNATIONAL LASER PHYSICS WORKSHOP
(LPHYS'2000)

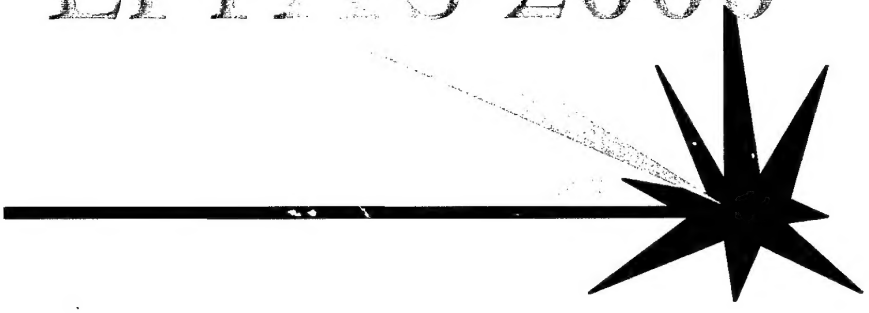
Bordeaux, France, July 17-21, 2000

Final Report
F61775-00-WF034
CSP00-5034

BOOK of ABSTRACTS

Oral Papers

LPHYS'2000



DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

DTIC QUALITY INSPECTED 4

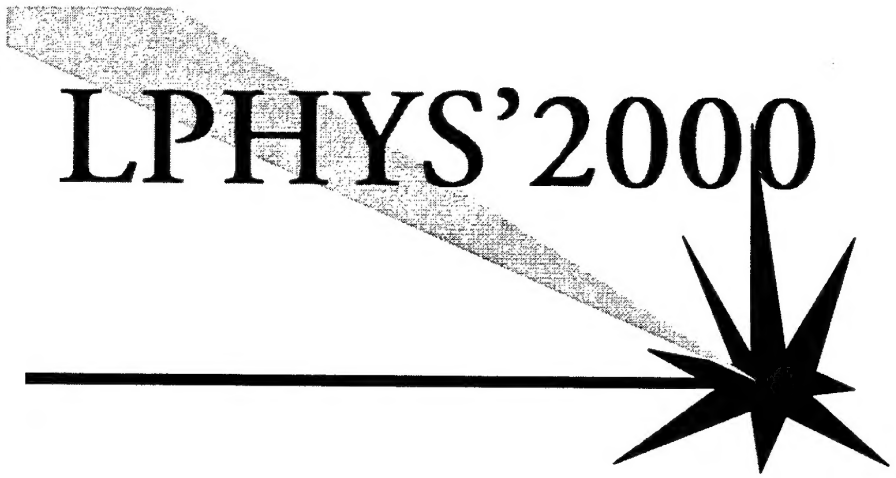
20000913 071

9th ANNUAL INTERNATIONAL LASER PHYSICS WORKSHOP
(LPHYS'2000)

Bordeaux, France, July 17-21, 2000

BOOK of ABSTRACTS

Oral Papers



AQ F00-12-3870

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	2000	Conference Proceedings

4. TITLE AND SUBTITLE

9th Int'l Workshop on Laser Physics - LPHYS 2000', Oral Papers

5. FUNDING NUMBERS

F61775-00-WF

6. AUTHOR(S)

Conference Committee

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

General Physics Institute of the Russian Academy of Sciences
38 Vavilova str.,
Moscow 117942
Russia

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

CSP 00-5034

11. SUPPLEMENTARY NOTES

Two volumes: Oral Papers and Posters

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words)

The Final Proceedings for 9th Int'l Workshop on Laser Physics - LPHYS 2000', 16 July 2000 - 21 July 2000

This is an interdisciplinary conference. Topics include quantum nucleonics and short wavelength lasers, intense short pulse propagation & material interactions, strong field phenomena, physics of cold atoms, physics of lasers, and laser methods in medicine and biology.

14. SUBJECT TERMS

EOARD, Non-linear Optics, Laser cooling and atom optics, Induced gamma emission

15. NUMBER OF PAGES

200

16. PRICE CODE

N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Plenary Sessions

Monday, July 17, 2000

WELCOME REMARKS

09.00-09.10 P.P. Pashinin (Russia)
Deputy Chairman of the Workshop

09.10-09.25 G. Petite (France)
Scientific Coordinator of the Workshop, the Member of the Steering Committee, Chairman of the Local Organizing Committee

09.25-09.30 I.V. Yevseyev (Russia)
The Member of the Steering Committee, Deputy Editor-in-Chief of Laser Physics journal

Chair: G. Petite (France)

09.30-10.30 Joseph H. Eberly (Rochester, USA) and Stanley J. Haan (Grand Rapids, USA)
Overview of Short-Pulse Double Photoionization at High Laser Intensity as Examined by Numerical Simulation

Tuesday, July 18, 2000

Chair: V.M. Yermachenko (Russia)

09.00-09.45 Gerhard Rempe (Garching, Germany)
Cavity QED with individual atoms

Chair: C.M. Bowden (USA)

09.45-10.30 Peter L. Knight (London, UK)
Quantum Information Processing in a Dissipative Environment

Wednesday, July 19, 2000

Chair: W.P. Schleich (Germany)

09.00-09.45 Sandro De Silvestri (Milan, Italy)
Generation of Few Optical Cycle Pulses for Ultrafast Spectroscopy and Extreme Non-Linear Optics

Chair: J.H. Eberly (USA)

09.45-10.30 Gerhard J. Müller (Berlin, Germany)
Laser Optics in Medical Diagnostics and Therapy

Thursday, July 20, 2000

Chair: H. Walther (Germany)

09.00-09.45 Linn D. Van Woerkom (Columbus, USA)
Above Threshold Ionization as a Probe of Multielectron Effects in Atoms

Chair: F. Salin (France)

09.45-10.30 Vladilen S. Letokhov (Troitsk, Russia)
Atom and Light Nanooptics

Friday, July 21, 2000

Chair: W. Sandner (Germany)

09.00-09.45 Serge Haroche (Ecole Normale Supérieure, France)
Atoms and photons in a box: experiments on entanglement, decoherence and the quantum classical boundary

Chair: A. Migus (France)

09.45-10.30 Sergey N. Bagayev (Novosibirsk, Russia)
High-Precision Femtosecond Spectroscopy and its Applications

Chair: S.L. Chin (Canada)

14.30-15.15 Rafat R. Ansari (Cleveland, USA)
Monitoring Astronaut Health with Laser Light

Chair: K.A. Prokhorov (Russia)

15.15-16.00 Karl Kompa (Garching, Germany)
Quantum Mechanical Aspects of Photobiology

Chair: M.V. Fedorov (Russia)

16.00-16.30 Closing Remarks

J.H. Eberly, Rochester Theory Center and Department of Physics and Astronomy, University of Rochester, Rochester NY 14627 USA

S.L. Haan, Department of Physics and Astronomy, Calvin College, Grand Rapids, MI 49546 USA

Title -- Overview of Short-Pulse Double Photoionization at High Laser Intensity as Examined by Numerical Simulation

Abstract -- We present an overview of high-intensity double-ionization physics, from the viewpoint of numerical solutions of Schrödinger's equation for model two-electron atoms. We examine the time development of the spatial population density and see evidence of both recollision and sequential ionization, with the latter becoming increasingly dominant with increasing laser intensity. We consider several laser frequencies and intensities, and we explore the importance of interaction between the two electrons in single and double ionization by systematically adjusting the "correlation charge." We probe an enhancement in the single- and double-ionization yields which occurrs at certain laser intensities in several helium models. The enhancement is attributed to a specific even-parity transition which becomes resonant due to Stark level shifts.

"Generation of few optical cycle pulses for ultrafast spectroscopy and extreme non-linear optics"

Sandro De Silvestri

During the last few years the race towards the generation of shorter and shorter light pulses has become very exciting with important achievements. The main goals are frequency tunability in a wide spectral range and high peak power. The former is essential for applications in several advanced ultrafast spectroscopic experiments, such as photon echoes and vibrational wave-packet dynamics, the latter for non-linear optics experiments performed in presence of high field.

We will present two techniques for generating extremely short light pulses, which have been recently developed in our research group. These are based on pulse compression and allow addressing either the issues of pulse tunability or high peak power. In pulse compression, two fundamental steps have to be accomplished: (i) generation of extra-bandwidth by means of suitable non-linear optical processes; (ii) re-phasing all the new frequency components in such way that they add constructively at the peak of the pulse and destructively at the wings. Under these conditions, according to the Fourier theorem, pulse duration will be inversely proportional to the generated extra-bandwidth. With these tools many optically initiated fast-occurring processes in physics can now be studied with an unprecedented time resolution. We will present some applications to extreme non-linear optics and to study of vibrational wave packet dynamics in real time in organic compounds.

Cavity QED with individual atoms

Gerhard Rempe

Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

In quantum physics, one usually considers an ensemble of identically prepared objects. Only recently it became possible to realize individual quantum systems in the laboratory and observe their temporal evolution in real time. One of the most fundamental quantum optical systems in this context is a moving atom strongly coupled to a single photon.

The talk discusses several experiments performed with one [1] or a few [2] ultra-cold atoms moving through the standing-wave light field of a high-finesse optical resonator excited with less than one photon on average. The light emitted from the resonator serves to observe the atomic motion with high spatial and temporal resolution. This allows to investigate in detail single-photon light forces. In particular, a simple feed-back switch triggered by the atomic motion allows to control the excitation of the system depending on the atom's position. This made possible to monitor in real time a single atom approaching the resonator, catch it with single photons and observe the subsequent motion of the trapped atom [3,4]. The experiment confirms the existence of a novel atom-photon molecule.

The results open up new possibilities for cooling atoms or molecules. They make possible to study the motion of atoms in non-classical light fields, or investigate fundamental systems for quantum information processing.

[1] P. Münstermann et al., Phys. Rev. Lett. **82**, 3791 (1999)
[2] P. Münstermann et al., Phys. Rev. Lett. 84, 4068 (2000)
[3] C.J. Hood et al., Science **287**, 1447 (2000)
[4] P.W.H. Pinkse et al., Nature **404**, 365 (2000)

Laser Optics in Medical Diagnostics and Therapy

GERHARD MUELLER[1,2], B. SCHALDACH[1], A. ROGGAN[1],
J. HELFMANN[2], J. BEUTHAN[1]
- [1] Freie Universitaet Berlin, Universitaetsklinikum Benjamin Franklin, Institut fuer Medizinische/Technische Physik und Lasermedizin (WE09), Krahmerstr. 6-10, 12207 Berlin - [2] Laser- und Medizin-Techologie gGmbH, Krahmerstr. 6-10, 12207 Berlin

The application of optical process technologies in biological tissue requires a specific understanding of light propagation in strongly scattering media. New measuring technologies and computer-aided simulation methods have brought about a breakthrough. In this paper methods for quantitative determination of the optical constants μ_a (absorption coefficient), μ_s (scattering coefficient) and the phase function, characterized by the so-called g-factor, are demonstrated and related therapy methods, such as laser-induced thermal therapy, methods of antirheumatism diagnostics and laser Doppler blood flow determination, explained. In addition to light propagation in clouded media, non-linear optical processes, such as photoablative methods in laser angioplasty and in laser lithotripsy, too, have gained in importance in medical therapy and diagnosis.

"Above-Threshold Ionization as a Probe of Multielectron Physics"

L. D. Van Woerkom, M. J. Nandor, M. A. Walker, G. Gillen, H. G. Muller*

Department of Physics, The Ohio State University
174 W. 18th Avenue, Columbus, Ohio 43210-1106, USA
voice: 614-292-9626; fax: 614-292-7557
email: LVW@mps.ohio-state.edu

*FOM Institut voor Atoom-en Molekuulfysica,
1098 SJ Amsterdam, Netherlands

Abstract

The study of above-threshold ionization (ATI) is now over 20 years old and much has been learned about the interaction of a single electron with intense laser fields. The development of stable, high repetition rate ultrashort pulse laser systems has allowed experiments to probe intricate details of the ionization process using photoelectron and photoion spectroscopies. To date the overwhelming majority of data show that intense laser fields interact with only single electron at a time to produce the well known features in electron kinetic energy spectra. We will present an overview of state-of-the-art experiments in ATI and show what can be learned about multielectron effects using careful measurements. Argon data showing the dominance of single electron physics at laser intensities near and below 10^{14} W/cm^2 will be shown as well as new data taken above 10^{15} W/cm^2 showing electrons from double ionization. In addition, new data taken with a model two-electron system (magnesium) continues the search for detailed a understanding of intense field interactions in complex atoms. In all cases the current status of what we learn using ATI will be shown and discussed.

MONITORING ASTRONAUT HEALTH WITH LASER LIGHT

Rafat R. Ansari
NASA Glenn Research Center
National Center for Microgravity Research on Fluids & Combustion
Mail Stop 333-1, 21000 Brookpark Road, Cleveland, OH 44135
Phone: (216) 433-5008, Fax: (216) 977-7138
E-mail: **rafat.r.ansari@grc.nasa.gov**

The motivation for this talk comes from the human experience and achievements in space flight. In less than 50 years the human-kind has launched rockets into space, went to moon and returned safely back to earth, learned how to live and work in space environment, sent probes to distant planets and obtained detailed images of geological features, repaired orbiting telescopes and satellites, and constructed complex permanent structures. The people from ancient Greeks to modern day civilizations have asked the question: is there life on Mars? We do not know the answer to this important age-old question, but as space faring people we can safely say that some day there will be life on Mars. This talk is in anticipation for that day when human species will land on Mars and we will be ready to monitor their health remotely, safely, non-invasively, and quantitatively to guarantee their safe and healthy return back to Earth.

A goggles-like head-mounted device equipped with several non-invasive and quantitative techniques for non-invasive medical evaluation of the eye, skin, and brain will be discussed for monitoring the health of astronauts during long-term space travel and exploration. Real-time non-invasive evaluation of the different structures within these organs will provide indices of the health of not just these organs, but the entire body. The techniques such as dynamic light scattering (for the early detection of cataracts to evaluate effects of cosmic radiation), corneal autofluorescence (to assess extracellular matrix biology (e.g., diabetes), optical polarization (of anterior ocular fluid to evaluate blood-glucose levels), laser Doppler velocimetry (of retinal, optic nerve, and choroidal blood flow to assess ocular as well as central nervous system blood flow), reflectometry/oximetry (for oxygen metabolism), optical coherence tomography (for retinal microstructure), and possibly scanning laser technology for intraocular imaging and scanning will be integrated into this compact device. Skin sensors will also be mounted on the portion of the device in contact with the periocular tissues. This will enable monitoring of body temperature and EEG. This device will monitor astronaut health during long-duration space travel by detecting aberrations from pre-established "norms", enabling prompt initiation of early preventative/curative therapy. The use of non-invasive technologies permits frequent repetition of tests, enabling real-time monitoring. It will also be a device for tele-medicine for use in diseases not adequately diagnosed and/or treated in under-served areas on Earth as well as in so-called "advanced" care settings (e.g. diabetes in the USA).

Seminar 1
Modern Trends in Laser Physics

Monday, July 17, 2000

11.00-16.00 QUANTUM NUCLEONICS AND SHORT-WAVELENGTH LASING

Chairs: L. Rivlin (Russia) and M. Stickley (UK) **Session 1.1**

11.00-11.30 C.B. Collins, A.C. Rusu, N.C. Zoita, M.C. Iosif, D.T. Camase, F. Davanloo, F.J. Agee (USA); J.M. Pouvesle, R. Dussart (France); C.A. Ur, I.I. Popescu (Romania); V.I. Kirischuk, N.V. Strilchuk (Ukraine)
Status and issues for the year 2000 in the study of gamma emission from isomeric 178-Hf induced by X-ray irradiation

11.30-12.00 J.J. Carroll, M.K. Boyle, Y. Kaneko (Youngstown, USA), S.A. Karamian (Dubna, Russia), M. Helba, H. Roberts (Huntsville, USA) and F.J. Agee (AF Office of Sci. Research, USA)
Method for detection of x-ray triggered decay of the ^{178m2}Hf isomer using a multidetector array

12.00-12.30 L. Rivlin (Moscow, Russia)
On the problem of forced release of nuclear energy of longlived isomers

12.30-13.00 G. Claverie, T. Carreyre, J.F. Chemin, M. Harston and G. Malka (Bordeaux, France)
Nuclear excitations with lasers

13.00-14.00 Lunch

Chairs: J.J. Carroll and J.F. Chemin (France) **Session 1.2**

14.00-14.30 J. Zavada (London, UK)
Excitation and luminescence of rare earth atoms in gallium nitride thin films

14.30-14.50 A.V. Andreev, R.A. Chalykh, O.V. Chutko, A.M. Dykhne, V.M. Gordienko, P.M. Mikheev, A.B. Savel'ev, and E.V. Tkalya (Moscow, Russia)
Nucleus excitation in hot dense laser plasma: application to spectroscopy and feasibility of G-lasing

14.50-15.10 V.V. Samartsev, S.N. Andrianov (Kazan, Russia)
Triggering launch of the cascade gamma superradiance

15.10-15.30 A.A. Zadernovsky (Moscow, Russia)
Stimulated Gamma-emission by Anti-Stokes Transitions of Free Isomeric Nuclei

15.30-15.45 J.J. Carroll (Youngstown, USA)
Photon cross sections for excitation and deexcitation of nuclear isomers: I. ^{180}Ta revisited

15.45-16.00 S.A. Karamian (Dubna, Russia) and J.J. Carroll (Youngstown, USA)
Photon cross sections for excitation and deexcitation of nuclear isomers: II. Theoretical prediction

16.00-16.30 Coffee Break

Chairs: R. Shakhmuratov (Belgium) and F. Vallée (France) **Session 1.3**

16.30-17.05 V. Shalaev, Z.C. Ying, W. Kim, V.P. Drachev, V.P. Safonov, and R.L. Armstrong (Las Cruces, USA)
Fractal nano-gyro and fractal micro-laser

17.05-17.30 C.Sibilia, M.Bertolotti, M.Centini (Roma, Italy), M. Scalora, C.M. Bowden (Redstone Arsenal, USA)
Nonlinear Optical Propagation in periodical and quasiperiodical layered structures

17.30-17.55 A.M. Zheltikov, A.V. Tarasishin, and S.A. Magnitskii (Moscow, Russia)
Matching Phase and Group Velocities in Second-Harmonic Generation in One-Dimensional Photonic Band-Gap Structures

17.55-18.15 L.A. Golovan, A.B. Fedotov, P.K. Kashkarov, and A.M. Zheltikov (Moscow, Russia)
Dispersion control in porous silicon multilayers

18.15-18.35 F.K. Tittel, A.A. Kosterev, R.F. Curl (Houston, USA), C. Gmachl, F. Capasso, D.L. Sivco, J.N. Baillargeon, A.L. Hutchinson, and A.Y. Cho (Murray Hill, USA)
Absorption spectroscopy with quantum cascade lasers

Tuesday, July 18, 2000

Chairs: C. Hood (USA) and V. Samartsev (Russia) — **Session 1.4**

11.00-11.35 J.H. Eberly (Rochester, USA)
Deconstructing continuous entanglement for photon localization

11.35-12.00 J. Bergou (New York, USA; Pécs, Hungary), M. Hillery and Y. Sun (New York, USA)
Optimum distinction of nonorthogonal states in quantum mechanics: an optical realization

12.00-12.35 G.R. Welch, I. Novikova, E. Mikhailov, V.L. Velichansky, Y. Rostovtsev, M.O. Scully (Texas, USA)
Experiments with slow light

12.35-13.00 R.N. Shakhmuratov, R. Coussement, J. Odeurs (Leuven, Belgium), A. Szabo (Ottawa, Canada), G. Kozyreff and P. Mandel (Bruxelles, Belgium)
Dark and bright states of the coherently excited atom

13.00-14.30 Lunch

Chairs: C Flytzanis (France) and C. Sibilia (Italy) — **Session 1.5**

14.30-15.05 L. Lugiato (Como, Italy)
Spatial quantum entanglement and optical images

15.05-15.35 R. O'Connell (Baton Rouge, USA)
Quantum noise effects in strongly driven systems

15.35-16.05 A. Shumovsky and A. Klyachko (Bilkent, Turkey)
The problem of localizing photons

16.05-16.30 E. Manykin (Moscow, Russia)
Quantum interference, coherent control and laser isotope separation

16.30-17.00 Coffee Break

Chairs: V. Shalaev (USA) and J. Zavada (UK)
Session 1.6

17.00-17.30 J.E. Sipe (Toronto, Canada)
Quantum interference and nonlinear optics

17.30-18.00 C. Voisin, D. Christofilos, N. Del Fatti and F. Vallée (Palaiseau, France)
Ultrafast electron dynamics in metal nanoparticles

18.00-18.30 R. Frey, M. Haddad, C. Flytzanis (Palaiseau, France), R. André, J. Cibert (Grenoble, France)
Nonlinear Gyrotropy. Photoinduced Faraday rotation in semimagnetic semiconductor nanostructures

18.30-18.55 Yu.E. Lozovik, A.L. Dobryakov, V.M. Farztdinov, S.P. Merkulova (Troitsk, Russia), S.A. Kovalenko, N.P. Ernsting (Berlin, Germany)
Femtosecond laser spectroscopy of underdoped $YBa_2Cu_3O_{7-\delta}$: marginal or two-dimensional Fermi liquid?

18.55-19.20 G. Petite (Paris, France) and A. Shvartsburg (Moscow, Russia)
Artificial dispersion of inhomogeneous and non-stationary media - exactly solvable models

Wednesday, July 19, 2000

Chairs: R. Frey (France) and K. Prokhorov (Russia) — **Session 1.7**

11.00-11.35 H. Walther (München and Garching, Germany)
Cavity quantum electrodynamics with trapped ions

11.35-12.05 C.J. Hood, T.W. Lynn, D.W. Vernooy, J. Ye, A.C. Doherty, H.C. Nagerl, D.M. Stamper-Kurn and H.J. Kimble (Pasadena, USA)
Real-time manipulation of single, strongly coupled atoms

12.05-12.30 V.A. Reshetov (Togliatti, Russia) and I.V. Yevseyev (Moscow, Russia)
On the polarization properties of one-atom micromasers

12.30-12.55 M. Lukin (Harvard, USA)
Quantum optics with "slow" and "trapped" light

Thursday, July 20, 2000

Chairs: M. Lukin (USA) and V. Shuvalov (Russia) **Session 1.8**

11.00-11.30 E. Wintner, I.T. Sorokina, E. Sorokin (Vienna, Austria)
Diode-pumped ultrashort pulse lasers

11.30-12.00 I.A. Bufetov, E.M. Dianov, A.M. Prokhorov (Moscow, Russia)
Near IR CW laser-diode-pumped Raman fiber lasers

12.00-12.30 V.I. Yukalov and E.P. Yukalova (Dubna, Russia)
Enhancement of spin superradiance by hyperfine interactions

13.00-14.30 Lunch

Chairs: L. Lugiato (Italy) and A. Shumovsky (Turkey) **Session 1.9**

14.30-15.00 E.V. Degtiarev (Las Cruces, USA), A.V. Larichev, I.P. Nikolaev (Moscow, Russia), V. Wataghin (Turin, Italy)
Nonlinear optical models with multiparameter bifurcations

15.00-15.25 V.A. Makarov, S.M. Donskoi (Moscow, Russia)
Five-wave-mixing process $\omega_b = \omega_1 + \omega_1 + \omega_1 - \omega_2$ for studying chiral molecules in solution

15.25-15.50 V.A. Zuikov, A.A. Kalachev, V.V. Samartsev, A.M. Shegeda (Kazan, Russia)
Two-color optical superradiance in the optically dense $LaF_3:Pr^{3+}$ crystal

16.30-17.00 Coffee Break

17.00-19.00 INTENSE SHORT LASER PULSE PROPAGATION IN AIR
(Joint Session with the Strong Field Phenomena Seminar)

Chair: C. Bowden (USA) **Session 1.10 & 2.10**

17.00-17.30 R. Sauerbrey, S. Niedermeier, J. Kasparian (Jena, Germany), D. Mondelain, J.-P. Wolf, J. Yu (Villeurbonne, France), Y.-B. André, M. Franco, A. Mysyrowicz, B. Prade, S. Tzortzakis (Palaiseau, France), M. Rodriguez, H. Wille, L. Wöste (Berlin, Germany)
High intensity laser-beam propagation in the earth atmosphere

17.30-17.55 S.L. Chin, A. Talebpour, Mahmoud Abdel-Fattah (Quebec, Canada)
Clean Molecular Fluorescence and a new type of LIDAR

17.55-18.20 A. Mysyrowicz, S. Tzortzakis, Y-B. André, M. Franco, B. Prade (Palaiseau, France)
Self-guided propagation of intense femtosecond laser pulses through atmosphere

18.20-18.40 J.V. Moloney (Tucson, USA)
Optically turbulent femtosecond light strings

18.40-19.00 N. Aközbek and C.M. Bowden (Huntsville, USA), A. Talebpour and S.L. Chin (Quebec, Canada)
Femtosecond pulse propagation in air: Beyond the slowly varying envelope approximation

Friday, July 21, 2000

Chairs: E. Wintner (Austria) and A. Zheltikov (Russia) **Session 1.11**

11.00-11.30 V.V. Shuvalov, V.M. Petnikova, K.V. Rudenko (Moscow, Russia)
Ultra-fast cooling of electronic subsystem of ultra-thin Ni films: studying by coherent four-photon picosecond spectroscopy

11.30-12.00 S.M. Klimentov, S.V. Garnov, T.V. Kononenko, V.I. Konov, P.A. Pivovarov (Moscow, Russia), and F. Dausinger (Stuttgart, Germany)
Ablation rate enhancement by combination of picosecond and nanosecond laser pulse trains

Status and Issues for the Year 2000 in the Study of Gamma Emission from Isomeric ^{178}Hf Induced by X-ray Irradiation

by

C. B. Collins[1], A. C. Rusu, N. C. Zoita, M. C. Iosif, D. T. Camase and F. Davanloo
Center for Quantum Electronics, University of Texas at Dallas, PO Box 830688, Richardson, Texas, 75083-0688, USA

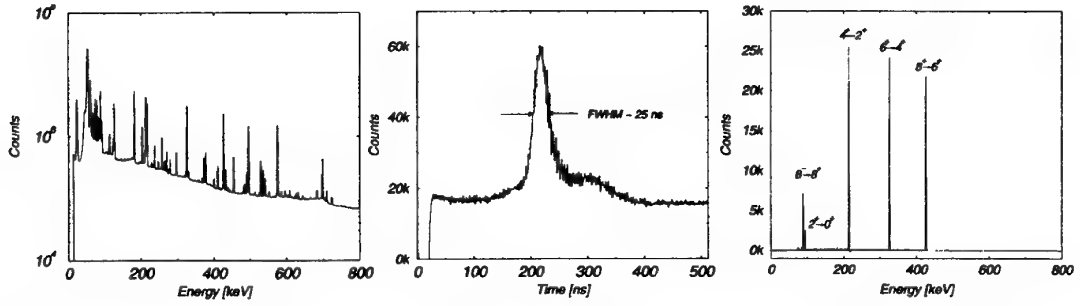
F. J. Agee
Air Force Office of Scientific Research, AFOSR/NE, 801 N. Randolph St. Arlington, VA 22203-1977

J. M. Pouvesle[2] and R. Dussart
GREMI, CNRS - Universite d'Orleans, Orleans, France

C. A Ur and I. I. Popescu
H. Hulubei NIPNE and IGE Foundation, Bucharest, Romania

V. I. Kirischuk and N. V. Strilchuk
Scientific Center "Institute for Nuclear Research," Kiev, Ukraine

Two years ago we first described how the electromagnetic decay from the 31-year isomeric state of ^{178}Hf at 2.446 MeV above the ground state could be accelerated by irradiating with x-ray pulses at peak power levels of only mW cm^{-2}. [1] A 2.0% ± 1.3% increase of emission in the ground state band (GSB) was observed when the bremsstrahlung component of the irradiating spectrum had an end-point energy of 90 keV. It was straightforward to compute from the number of isomeric nuclei, the irradiating flux, and the size of the effect, that the integrated cross section (ICS) was of unprecedented magnitude for the excitation of the isomeric state to an intermediate state able to decay by subsequent cascade toward the GSB. A year ago, additional experiments reconfirmed these experimental results and raised confidence limits for the observation to about 6σ while demonstrating that the parts of the irradiating continua causing the effect had E≤20 keV. [2] In 2000 experiments entered a new phase which benefitted from additional technologies for the control of the irradiation and for the multi-parametric acquisition of fluorescent photons to facilitate study of the induced transition cascades from the isomeric nuclei. Shown below is a typical improvement from fast coincidence analysis of the data, now made possible.



Spectrum of isomeric ^{178}Hf and impurities. Selection of coincident photons. Photons coincident with GSB.

[1] C.B. Collins et al., Laser Physics 9, 8 (1999); Phys. Rev. Lett. 82, 695 (1999).
[2] C.B. Collins et al., Phys. Rev. C (Apr. 2000).

[1] Communicating Author, cbc@utdallas.edu

[2] Presenting Author, Jean-Michel.Pouvesle@univ-orleans.fr

Method for detection of x-ray triggered decay of the ^{178m2}Hf isomer using a multidetector array

J. J. Carroll,[1] S. A. Karamian,[2] M. K. Boyle,[1] Y. Kaneko,[1] M. Helba,[3] H. Roberts[3] and F. J. Agee[4]

[1] *Department of Physics and Astronomy, Center for Photon-Induced Processes, Youngstown State University, Youngstown, Ohio 44555, USA*

[2] *Joint Institute for Nuclear Research, Dubna, Moscow Region 141980, RUSSIA*

[3] *SRS Technologies, Inc., Huntsville, Alabama, USA*

[4] *Air Force Office of Scientific Research, USA*

Experiments reported during the 1990's with the high-spin, 31-year-lived ^{178m2}Hf nuclear isomer have been recognized as intriguing tests of multi-quasiparticle state structures and their interactions with external radiation. A triggered release of the stored isomeric energy (2.5 MeV per nucleus, or 1.2 GJ/gram) is also very promising for applications, such as the creation of a pulsed γ-ray source controlled by a soft x-ray device. The observation of accelerated decay of the ^{178m2}Hf metastable level under irradiation by 90-keV bremsstrahlung was recently reported in Ref. [1]. Experimentally, it was quite difficult to distinguish the branch of the γ-cascade triggered by external radiation in the presence of a high-intensity background created by the spontaneous decay of ^{178m2}Hf itself, as well as by the contaminant ^{172}Hf activity present in the source. Thus, only a small increase in the intensity of the decay γ lines could be deduced and the details of the physical process remain unclear. The development of new, more sophisticated, experiments are therefore extremely important.

Triggering of a nuclear level depopulation is interpreted as a two-step process when, after absorption of the incident photon, an intermediate state is excited and then decays to the ground state band (GSB). The mediating state has to have special properties, in particular, a large width and a wave function supporting a violation of the K quantum number (this would give a so-called "K-mixed" intermediate state). Such a level is not yet known among levels of ^{178}Hf, accordingly to modern level schemes, although strongly K-mixed levels have been observed in other nuclides. After the experiment of Ref. [1], it must be assumed that such a level is present within 90 keV above the isomeric state. It seems quite probable that upon excitation, this mediating level decays to the ground state via a high multiplicity γ-cascade, a decay path other than the spontaneous decay path. Some indications of this were also seen in the first experiment [1].

Such an inherent property for the triggered depopulation allows the proposal of a new method by which to separate the triggered from the spontaneous decay in the ^{178m2}Hf case. The concept is based on the measurement of the total energy of a γ-cascade by an array of NaI detectors in coincidence with a high resolution measurement of a single γ-ray spectrum using a Ge detector. The combination of a total energy value of $\sum E_i > 2$ MeV with characteristic γ lines from the ^{178}Hf GSB would be enough to separate the triggered depopulation events from both ^{178m2}Hf and ^{172}Hf $\rightarrow$ ^{172}Lu spontaneous decays. For the latter, decay γ rays are emitted mostly in electron capture decay of ^{172}Lu while the lifetime is determined by the precursor ^{172}Hf.

Correlated sum energy - multiplicity spectra for cascades of γ rays emitted from the ^{178m2}Hf (^{172}Hf) source were measured in Ref. [2]. It was shown that decay of ^{178m2}Hf produces two peaks in the sum energy spectrum: one near 0.9 MeV and another at 1.3 MeV. The ^{172}Lu decay supplies an energy of about 1.9 MeV. So, detection of high-energy events $\sum E_i > 2$ MeV excludes the spontaneous ^{178m2}Hf radiation, and the observation of the ^{178}Hf GSB lines in the Ge spectrum excludes ^{172}Lu. A high multiplicity of events, $M > 4$, also indicates a non-spontaneous decay. Only triggered decay of ^{178m2}Hf, with its unusual cascade bypassing the 4-s ^{178m1}Hf isomer, satisfies the described selection of events. A strict selection also makes sure that there is an absence of any significant background.

The multi-detector γ-array is under construction now at Youngstown State University. Two Ge detectors are combined with six NaI of 3" x 3" size. Multiple coincidences make the rate of random coincidences insignificant. A compact array of the detectors supplies a total detection efficiency of about 80 % for E_γ <0.6 MeV. The ^{178m2}Hf sample is placed in center of the array and in upcoming experiment will be exposed to the pulsed x-ray radiation from an exterior x-ray device.

1. C. B. Collins, F. Davanloo, M. C. Iosif, R. Dussart, J. M. Hicks, S. A. Karamian, C. A. Ur, V. I. Kirischuk, J. J. Carroll, H. E. Roberts, P. McDaniel and C. E. Crist, Laser Physics 9, 8 (1999).

2. R. Kulessa, J. Gerl, H.-J. Wollersheim, H. Xie, S. A. Karamian, Yu. Ts. Oganessian, Ch. Briancon, M. Hussonois and Ch. Ender, GSI Scientific Report, Darmstadt, 1992, p. 86.

On the Problem of Forced Release of Nuclear Energy of Longlived Isomers

by

Lev A. Rivlin

MIREA Technical University
78 Vernadsky Ave., Moscow, 117454, RUSSIA
Phone: +7 095 434 7247. FAX: +7 095 434 9317
E-mail: <rla@superlum.msk.ru>

We consider a new type of nuclear chain reaction, namely, a reaction of antistokes radiative transitions of longlived metastable isomers triggered by quasi-equilibrium black body radiation of a dense hot plasma which relatively high temperature is supported in its part by absorption of gamma-photons emitted by nuclei. As result the energy stored in metastable isomer states is released and an intense burst of gamma-photons is emitted.

Quantitative estimates are presented.

This work partially was supported by INTAS (Grant 97-31566).

Nuclear excitation with lasers

G. Claverie, T. Carreyre, J. F. Chemin, M. Harston, G. Malka

Centre d'Etudes Nucleaires de Bordeaux-Gradignan, 33175 Gradignan, France

In spite of the low energy of the photons in a laser beam, typically of the order of one eV, recent experiments show that the excitation of the nucleus is feasible in laser-solid interaction. This is due to the large intensity of energetic photons produced in a large frequency range from low energy X-rays to γ-rays when a high powerfull laser beam interacts with solid targets. Two domains of nuclear excitation are currently under investigation.

The first approach, called resonant excitation, concerns the excitation of low lying isomeric nuclear states in a plasma. In a dense plasma induced by lasers at temperatures of the order of 100 eV, a large number of atomic configurations are explored. In some cases, one atomic transition between two atomic states can energetically matches one transition between two nuclear states. Theoretical calculations show that the energy can be transferred through the residual electron-nucleus interaction to the nuclear part of the atom. This process called NEET (Nuclear Excitation by Electronic Transition), appears as a special mode of decay of the electronic system, competing with photon and Auger emission. Recent progress in the excitation of the 76 eV level in ^{235}U by laser will be reported.

The second approach is based on the well known photoexcitaton of the nucleus. It has been demonstrated that up to 10^{10} γ keV^{-1} st^{-1} with an energy larger than 10 MeV are produced in a single shot of petawatts lasers. The production of such a large number of energetic photons results from the Bremsstralhung radiation of high energy electrons produced by laser-solid interaction. The production of electrons in the relativistic regim starts to be important at laser intensity of 10^{18} Wcm^{-2}. Such energies are above the threshold for neutron production and photo-fission reactions leading to a possible utilisation of lasers for neutron sources.

EXCITATION AND LUMINESCENCE OF RARE EARTH ATOMS IN GALLIUM NITRIDE THIN FILMS

John M. Zavada

ARL-European Research Office, 223 Old Marylebone Road London NW1 5TH, UK
TEL 44-20-7514-4907, FAX 44-20-7724-1433
jzavada@usardsguk.army.mil

In this talk recent developments concerning the luminescence characteristics of rare earth-doped gallium nitride (GaN) thin films will be presented. Basic properties of the lathanide series of rare earth elements will be reviewed, along with the main methods for doping GaN thin films with such atoms. Several techniques for optical excitation of the trivalent rare earth ions will be discussed and luminescence spectra, in both the infrared and visible regions, will be presented. The emphasis will be on the optical properties of the trivalent rare earth ions of erbium (Er3+) and praesodymium (Pr3+). Changes in the luminescence characteristics due to differences in the doping method, the thermal treatment, and the background impurity levels will be discussed. Data showing the remarkable temperature stability of the Er3+ luminescence intensity from cryogenic to elevated temperatures will be presented. Various light emitting diodes that have been fabricated based on rare earth-doped GaN thin films will be described and the electroluminescence from the visible to the infrared that have been observed will be presented. Concepts for future applications will be discussed.

Nucleus excitation in hot dense laser plasma: application to spectroscopy and feasibility of γ-lasing

A.V.Andreev, R.A.Chalykh, O.V.Chutko, A.M.Dykhne, V.M.Gordienko, P.M.Mikheev, A.B.Savel'ev, and E.V.Tkalya

International Laser Centre, Physics Faculty and Institute of Nuclear Physics
M.V.Lomonosov Moscow State University, Moscow, 1 1 9899, Russia

Tel.: **+7(095)939-3092; Fax:+7(095)9393113,** e-mail: andreev@srl.ilc.msu.su

The temperature of hot electrons achieved in the dense plasma at moderate intensities of 10^{16}-10^{17} W/cm² has been proved to be enough to provide excitation of low energy nuclear stable isomers [1]. Besides promising applications of this process such as quantitative spectroscopy of low energy levels in metastable nuclear isomers, nuclear isotopes separation, the ultimate goal of γ-lasing using metastable isomers seems feasible [2].

Between different main mechanisms responsible for such excitation - photoexcitation by plasma X-rays, excitation through inelastic electron scattering and inverse internal electronic conversion, the first one has the highest cross section in hot dense femtosecond laser plasma. We discuss the impact of nuclear line broadening in plasma (due to ion-ion collisions, Doppler effect, Zeeman broadening by plasma self-generated magnetic field, Stark broadening, etc.) on the total number of excited nuclear isomers.

We detected low energy γ-quanta emission from Ta-181 plasma (Ta has 6.238 keV nuclear level). The experimentally assessed number of excited Ta-181 isomers in plasma is found to be in good agreement with the theoretically calculated value. In this calculation we considered only photoexcitation by plasma X-rays with Doppler broadened nuclear level.

We took into account that 6 keV X-rays have extinction length of 2 mcm, thus enlarging excitation volume. Temporal evolution of γ-quanta flux follows the known value of 6.05 mcs for half lifetime of this nuclear Ta level.

The same excitation process can be achieved while considering metastable nuclear isomers possessing low energy short lived levels. We consider plasma conditions where such an excitation could provide for population inversion followed by γ-lasing.

[I] A.V. Andreev, R.V.Volkov, V.M. Gordienko, et.al., "Excitation of tantalum-181 nuclei in a high temperature femtosecond laser plasma", JETP Lett. 69, 371-376 (1999).

[2] A.V.Andreev, V.M.Gordienko, A.B.Savel'ev, " Nuclear transition excitation in high-temperature near-surface plasma:feasibility of γ-lasing ». Proceedings of induced γ emission 97, Predeal, Romania, 16-20 August 1997, IGE Foundation, pp. 291-297

TRIGGERING LAUNCH OF THE CASCADE GAMMA SUPERRADINCE

V.V.Samartsev, S.N.Andrianov

Kazan Physical and Technical Institute of RAS

10/7 Sibirsky Trakt Str., Kazan, 420029, Tatarstan, Russia

phone: (8432)763681; fax: (8432)765075; e-mail: samartsev@dionis.kfti.kcn.ru

The possibility of the realization of the triggering launch of the cascade gamma superradiance is investigated using method of the nonequilibrium statistical Zubarev-Peletminsky operator. We show that if during the superradiance's delay time a weak injection pulse is directed toward a nuclear ensemble, the superradiance avalanche will begin almost just after this pulse. The frequency of the injection (triggering) pulse may differ from the gamma-superradiance frequency. Our theory shows, that this triggering launch may cause the cascade gamma superradiance with participation of few energy transitions. The conditions of the realization of the cascade gamma-superradiance are analyzed.

STIMULATED GAMMA EMISSION BY ANTI-STOKES TRANSITIONS OF FREE ISOMERIC NUCLEI

A.A.Zadernovsky

Moscow State Institute of Radio Engineering, Electronics, and Automation, 78 Vernadsky Ave., 117454 Moscow, Russia
Phone&Fax: +7(095)434-9317, E-mail: a.z@relcom.ru

We examine in detail a way to achieve a positive gain for stimulated gamma radiation based on the recently proposed concept for recoil assisted gamma-ray lasing [1] in cooled (monokinetized) beam of free isomeric nuclei.

As is well known, the centers of emission and absorption lines of a free nucleus are displaced by the double nuclear recoil energy. Modern methods for laser cooling of atoms containing isomeric nuclei allow to reduce the Doppler broadening to the extent sufficient for appearing the spectral splitting of emission and absorption lines of radiative gamma transitions. This results in formation of spectral-local population inversion in a cooled nuclear beam without excess of the number of excited nuclei over unexcited ones and leads to arising the amplification of stimulated radiation.

For discussion of anti-Stokes conversion of incident x- ray radiation into stimulated gamma emission of free isomeric nuclei we consider a three level system. A nucleus is initially in the metastable isomeric state from which it can decay very slowly to its ground state. Under the influence of a broadband external x-ray radiation we can force a two step decay to the nuclear ground state through an intermediate short-lived upper level. These triggering two-quantum transitions are accompanied by the absorption of x-ray photons with simultaneous emission of spontaneous or stimulated gamma-quanta. We present the cross section for the stimulated anti-Stokes resonance scattering with quanta of different multipolarity as well as the gain for stimulated gamma radiation in a cooled nuclear beam with spectral-local population inversion.

A screening of isotopes has been made in order to pick out the candidates with appropriate arrangement of the nuclear states. Numerical estimations executed for the selected isomers yield the threshold ratio for concentration of isomeric nuclei to overall nuclear concentration in the beam and the pumping threshold spectral photon flux density of x-ray radiation.

This work was partially supported by INTAS (Grant 97-31566).

[1] L.A.Rivlin, Quantum Electronics, 6, 467, 1999

Photon cross sections for excitation and deexcitation of nuclear isomers: I. ^{180}Ta revisited

J. J. Carroll
Department of Physics and Astronomy, Center for Photon-Induced Processes, Youngstown State University, Youngstown, Ohio 44555, USA

The nuclide ^{180}Ta has been the source of considerable interest for many years, being the least abundant isotope of the least abundant element on Earth. In addition, this isotope is the only naturally-occurring isomer since the 75-keV metastable state has a halflife in excess of 10^{15} y and the ground state has a halflife of only 8.2 h. Motivated by these unique properties, ^{180}Ta has been studied from a variety of perspectives, ranging from attempts to understand its stellar nucleosynthesis to evaluating its usefulness to support triggered gamma emission or even a gamma-ray laser. Due to the high photon baths in stars, and the suggestion that "optical" pumping might lead to triggered gamma emission, the deexcitation of this isomer by photons has remained a core concern.

The deexcitation of the ^{180}Ta isomer (^{180}Ta^m) using photons was first demonstrated in a simple experiment in 1987 [1]. It was shown that bremsstrahlung photons generated from a 6-MeV medical linac caused some of the population of isomers to be transferred to the ground state. Characteristic radiation emitted by daughter nuclides following the spontaneous decay of the ^{180}Ta ground state (^{180}Ta^g) was detected and photopeaks seen in high-purity Ge spectra were shown to reduce in intensity over time according to the known 8.2-h halflife. Due to the extremely long lifetime of ^{180}Ta^m, no significant activity in those daughters could be expected from spontaneous decay of the isomer. It was interpreted that the deexcitation process involved two steps: some of the bremsstrahlung photons were resonantly absorbed to excite an intermediate state from the isomer, followed by decay of the intermediate state through a branch which cascaded to the ground state. At that time, only an order-of-magnitude estimate of 100 eV b could be made for the integral cross section for photon deexcitation of ^{180}Ta^m since the accelerator had a fixed endpoint and the energy of the intermediate state was unknown..

A subsequent series of measurements [2] allowed two intermediate states (or narrow groupings of fragmented states) to be found near 2.8 and 3.6 MeV, with integral cross sections of 120 eV b and 350 eV b, respectively. These values are quite large and correspond to reduced transition probabilities of $B(E1) = 0.065$ and 0.148 W. u., respectively. Compared with the Recommended Upper Limit (estimated upper bound) on nuclear E1 transitions of 0.01 W. u., these values have been difficult to understand. In fact, to call attention to the magnitude of these values, the corresponding transitions have been called "giant" resonances.

Recently, a greatly improved experiment was conducted to further investigate the photon deexcitation of ^{180}Ta^m using a large enriched target, low-energy Ge detector and the high-current Stuttgart Dynamitron [3]. The 4,000-fold increase in sensitivity allowed intermediate states to be identified as low at 1 MeV, albeit with much smaller integral cross sections. The state at 1 MeV was determined to have an integral cross section of 0.057 eV b. The importance of this value to questions of nucleosynthesis has been discussed elsewhere. Regarding the implications for triggering of gamma emission, the existence of such lower-energy intermediate states requires a significant modification of the values of integral cross section assigned to the previously-measured states at 2.8 and 3.6 MeV. For the state at 2.8 MeV, most heavily referenced in discussions of triggered gamma emission, the integral cross section should be reduced by a factor of at least 4. In the case of a reduction by a factor of 4, the integral cross section becomes 30 eV b, leading to a reduced transition probability of $B(E1) = 0.016$ W. u. The final result is to bring this still quite strong transition into general agreement with expectations based on the systematics of nuclear transitions.

1. C. B. Collins, C. D. Eberhard, J. W. Glesener and J. A. Anderson, Phys. Rev. C **37**, 2267 (1988).
2. C. B. Collins, J. J. Carroll, T. W. Sinor, M. J. Byrd, D. G. Richmond, K. N. Taylor, M. Huber, N. Huxel, P. von Neumann-Cosel, A. Richter, C. Spieler and W. Ziegler, Phys. Rev. C **42**, 1813 (1990).
3. D. Belic, C. Arlandini, J. Besserer, J. de Boer, J. J. Carroll, J. Enders, T. Hartmann, F. Käppeler, H. Kaiser, U. Kneissl, M. Loewe, H. J. Maier, H. Maser, P. Mohr, P. von Neumann-Cosel, A. Nord, H. H. Pitz, A. Richter, M. Schumann. S. Volz and A. Zilges, Phys. Rev. Lett. **25**, 5242 (1999).

Photon cross sections for excitation and deexcitation of nuclear isomers: II. Theoretical prediction

S. A. Karamian[1] and J. J. Carroll[2]
[1] *Joint Institute for Nuclear Research, Dubna, Moscow Region 141980, RUSSIA*
[2] *Department of Physics and Astronomy, Center for Photon-Induced Processes, Youngstown State University, Youngstown, Ohio 44555, USA*

The cross section of triggered depopulation of isomeric states is a significant problem in the physics of nuclear reactions, as well as being important for applications in astrophysics and triggered γ emission. Experimental works are currently in progress aimed to detect the process of the isomer decay triggering by bremsstrahlung radiation, and to deduce the cross-section and probability values. Before the reliable experimental calibration, theoretical predictions for the cross sections of depopulation cannot be considered to be solid.

The triggered depopulation is regularly assumed to be a two-step process: first, absorption of a photon by the isomeric state (i) with excitation of an intermediate state (m), and second, decay to lower lying levels and eventually to the ground state (g). A special, K-mixed wave function should be assumed for the state (m) in order to provide a reasonable branching ratio for its decay to the low-K levels, in particular, to the ground state band. Recently, a few % enhancement of the decay-γ-line intensities was detected when a $^{178}Hf^{m2}$ isomeric source was exposed to a soft x-ray flux in comparison with the spontaneous decay rate. After the measurement of the spectral density of incident x-ray radiation, the integral cross section (ICS) was estimated [1] to be about 3×10^{-23} cm^2 keV, assuming that the resonance absorption energy is near 20 keV where the x-ray spectrum has a maximum. This experimental value is inconsistent with standard estimations, like that given in Ref. [2], predicting a few orders-of-magnitude lower value.

A modified Breit-Wigner cross section was suggested in Ref. [3] in order to eliminate this strong discrepancy. In accordance with the fundamental approach of Blatt and Weisskopf, the absorption cross section can be connected with the photon emission rate for the decay of an individual quantum state. This idea originated from the reversibility rule for the absorption-emission rates deduced from the classical Le Châtelier-Brown principle of detail balance known in statistical physics. Finally, based on the equal probabilities for the direct and reversed processes, a new equation for the ICS was derived, as follows:

$$\int \sigma_{ig}(E_\gamma)dE_\gamma = \frac{C}{E_\gamma^2}\pi\lambda^2 G\frac{\Gamma_{mi}}{(1+\alpha_{mi})\Gamma_{tot}}\frac{\Gamma_{mg}}{\Gamma_{tot}}\Gamma_{tot}. \qquad (1)$$

The partial widths Γ_{mi} and Γ_{mg} correspond to the decay branches from level (m) back to (i) and down to (g), respectively, while $\Gamma_{tot} = \Gamma_{mi} + \Gamma_{mg}$. Eq. (1) also contains the statistical spin factor, G, the electron-conversion coefficient, α_{mi}, and the geometrical cross section, $\pi\lambda^2$, where λ is the reduced wavelength of the incident radiation. The constant C can be found by normalization to experimental values, in particular, using the results from $^{180}Ta^m$ depopulation. The width parameters Γ are defined by the rate of the electromagnetic decay of the state (m), and the absorption cross section is connected with the decay rate (reversed process) as seen in Eq. (1).

Equation (1) predicts a few orders-of-magnitude higher ICS values than the standard approach of Ref. [2], and it is important in the context of recent experiments on triggered depopulation of nuclear isomers. In addition, applying Eq. (1) there is no necessity to contradict the systematics of reduced strengths of nuclear electromagnetic transitions for understanding the experimental ICS value. With a recommended maximum dipole strength of $B(E1) = 0.01$ W.u. (Weisskopf units), one can deduce an ICS value on the level of 10^{-23} cm^2 keV which is not far from the result of Ref. [1]. This value covers only 0.4% of the total strength of the giant dipole resonance, known as the GDR sum rule, nor does it contradict the γ-decay strength functions deduced from the analysis of (n, γ)-reaction data. The comparison of this new theoretical prediction with known nuclear systematics is discussed in the present talk.

1. C. B. Collins, F. Davanloo, M. C. Iosif, R. Dussart, J. M. Hicks, S. A. Karamian, C. A. Ur, I. I. Popescu, V. I. Kirischuk, J. M. Pouvesle, P. McDaniel and C. E. Crist, Yadernaya Fizika, **64** (in press for November 2000).
2. S. Olariu and A. Olariu, Phys. Rev. C **58**, 333 (1998).
3. S. A. Karamian, Proc. Intern. Conf. on LASERS'99, STS Press, McLean VA, 2000 (in press).

Fractal Nano-Gyro and Fractal Micro-Laser

Vladimir M. Shalaev, Z. C. Ying, W. Kim, V.P. Drachev, V.P. Safonov, and R.L. Armstrong
Department of Physics, MSC 3D, New Mexico State University, Las Cruces, NM 88003, U.S.A.
tel: (505) 646-1932, fax: (505) 646-1934, email: vshalaev@nmsu.edu

Giant effect of local optical activity in fractal aggregates of silver particles has been observed and studied by means of near-field scanning optical microscopy. The effect is due to surface-plasmon excitations localized on chiral-active nano-sized configurations of fractals. It is shown that seeding fractal colloid aggregates in microcavities can dramatically decrease thelasing threshold so that such fractal microlasers can operate at very low pumps and small densities of active media.

Nonlinear Optical Propagation in periodical and quasiperiodical layered structures

C.Sibilia, M.Bertolotti, M.Centini, M.Scalora (*), C.M. Bowden(*)

INFM at Dipartimento di Energetica-Universita' di Roma " la Sapienza"
Via Scarpa 16 -00161 Roma- Italy
(*)AMSAM-RD-WS-ST , U. S. Army Aviation & Missile
Research, Development, & Engineering Center
Redstone Arsenal, AL 35898, USA

The considered structures are obtained by alternating two dielectric layers of different refractive indices such that the highest refractive index layers belong to some fractal set. The triadic Cantor and the Fibonacci sets are considered as examples. The transfer matrix method is used and some of its properties are presented . Then the nonlinear transmission properties are discussed for second order nonlinear polarization . An analysis on phase matching conditions is presented. Additional analysis is performed when the input level intensity is so high to induce third order nonlinear polarization into the dielectric media constituting the structures . Mesoscopic model is also introduced.

Matching Phase and Group Velocities in Second-Harmonic Generation in One-Dimensional Photonic Band-Gap Structures

A.V. Tarasishin, S.A. Magnitskii, and A.M. Zheltikov

International Laser Center, Physics Faculty,
Moscow State University, Moscow, 119899 Russia

Improving the efficiency of nonlinear-optical interactions is one of traditional problems of nonlinear optics. Due to the rapid progress of femtosecond lasers, phase- and group-velocity matching of ultrashort laser pulses involved in nonlinear-optical wave mixing becomes one of the central issues on the agenda of this area of laser physics. Quasi-phase matching (QPM) [1] has received a wide acceptance as a method of improving the efficiency of second harmonic generation (SHG) [2]. The possibility of using photonic band-gap (PBG) structures for efficient second-harmonic generation was recently demonstrated by Scalora *et al.* [3].

In this paper, we present the results of analytical calculations and finite-difference time-domain simulations, showing that one-dimensional PBG structures allow phase and group velocities of the fundamental pulse and its second harmonic to be simultaneously matched for SHG involving ultrashort light pulses [4]. The second-harmonic intensity as a function of the nonlinear-interaction length in PBG frequency doublers may grow under these conditions faster than in the case of QPM structures, opening the way of achieving high efficiencies of frequency doubling regardless of the phase-matching length in the bulk of a nonlinear material (Fig. 1).

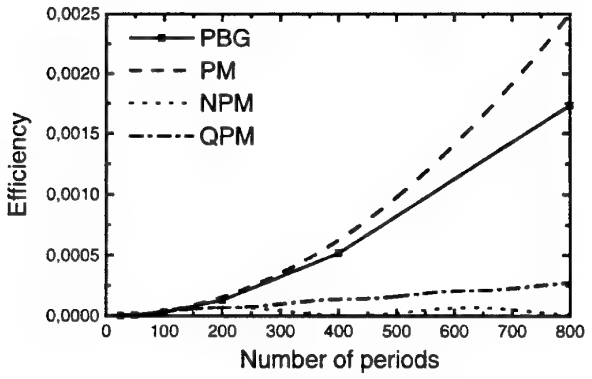


Fig. 1. Efficiency of SHG as a function of the nonlinear length for a PBG structure (solid line), QPM structure (dash-dotted line), and a nonlinear medium with phase and group-velocity mismatch (dotted line). The dashed line corresponds to the quadratic dependence of SHG efficiency on the interaction length.

References

1. J.A.Armstrong, N.Bloembergen, J.Ducuing, and P.S.Pershan, *Phys. Rev.* **127**, 1918 (1962).
2. M.M. Fejer, G.A.Magel, D.H.Jundt, R.L.Byer, *IEEE J. Quantum Electron.* **28**, 2631 (1992); R.L.Byer *J. Nonlinear Opt. Phys. Mater.* **6**, 549 (1997).
3. M.Scalora, M.J.Bloemer, A.S.Manka, *et al. Phys. Rev. A* **56**, 3166 (1997); M. Centini, C. Sibilia, M. Scalora, *et al., Phys. Rev. E* **60**, no. 4 (1999).
4. S.A. Magnitskii, A.V. Tarasishin, A.M. Zheltikov, *JETP Lett.* **70**, 819 (1999).

DISPERSION CONTROL IN POROUS SILICON MULTILAYERS

L.A. Golovan, A.B. Fedotov, P.K. Kashkarov, A.M. Zheltikov

M.V. Lomonosov Moscow State University, Faculty of Physics,

Moscow, 119899 Russia, Tel. +7 (095) 939 36 60, Fax +7 (095) 939 15 66,

e-mail: leo@ofme.phys.msu.su

Porous silicon (por-Si) is a very perspective material for the multilayer (or 1D photonic crystal) formation. Por-Si is well known due to its developed surface, possibility of nanocluster formation and simplicity of it production. A fabrication of multilayer periodic structures of por-Si alternate layers of different porosity allows the photonic band-gap to be formed. Varying the thickness of layers or angle of light incidence, it is possible to control the dispersion in por-Si photonic band-gap structures. That is why we investigated both in experiment and theoretically such processes in por-Si photonic band-gap structures as second harmonic generation, dispersion of group velocity and optical switching.

The multilayer structure was made by an electrochemical etching of a crystalline silicon wafer (100) in HF ethanol solution. To fabricate the structure alternate pulses of current density 5 and 105 mA/cm^2 were used. Varying the duration of the current pulses, we were able to control the layer thickness. Porosities of layers were about 70% (refractive index $n_1 = 1.4$) and 80% (refractive index $n_2 = 1.2$).

Second harmonic (SH) was pumped with laser system, consisted of passive mode-lock master oscillator with negative feedback and single pulse selection and amplification stage. Laser pulse had 35 ps duration and energy up to 3 mJ.

The dependence of the SH intensity on the azimuthal rotation angle is isotropic. SH is polarized in the plane of incidence. The SH generation is more efficient when pumping radiation is polarized in the plane of incidence, too. These effects may be explained by features of por-Si layers: optical isotropy in directions perpendicular to the normal to the surface and formation of silicon nanoclusters along the normal (for (100) surface). SH intensity from por-Si structure exceeded the SH intensities both from a crystalline silicon surface (100) and homogenous por-Si layer. The SH generation efficiency was found to be sensitive to the period of the structures. The dependences of the SH intensities on the angle of incidence is nonmonotonic. For the sample of highest SH effectiveness maximal signal is reached at the angle of incidence about 55°. For the samples with different periods SH intensity is much lower.

The analysis of phase mismatch of fundamental and SH radiation in such structures was carried out. Dispersion in a periodic structure was taken into consideration. According to our calculation the angle of minimal phase mismatch in structure A is 50° what is close to the experimental results.

The group velocity and its dispersion coefficient k_2 were calculated for por-Si multilayer. The results indicates possibility to use por-Si structures for compressing of short laser pulses as well as to correct distortion of the laser pulse caused by dispersion in media.

Por-Si multilayers are also proposed to use to implement the basic operations of Boolean algebra. Since the refractive index of a material depends on intensity, the edge of the photonic band-gap can be shifted. Thus, a reflected and transparent probing light beam is allowed to be switched in a controllable way, realizing NOR and OR logical functions.

This work was supported by Federal program "Surface atomic structures" (project 4.1.99), Moscow government grant No. A-059 and Russian Foundation for Basic Research (project 99-02-16664)

Absorption spectroscopy with quantum cascade lasers

A.A. Kosterev, R.F. Curl and F.K. Tittel
Rice Quantum Institute, Rice University, Houston, TX 77251-1892
akoster@rice.edu

C. Gmachl, F. Capasso, D.L. Sivco, J.N. Baillargeon, A. L. Hutchinson, and A.Y. Cho
Bell Laboratories, Lucent Technologies, 600 Mountain Avenue, Murray Hill, NJ 07974

Abstract

Recently developed quantum-cascade distributed feedback (QC-DFB) lasers [1] have been shown to be useful tunable single-frequency light sources for laser-based absorption spectroscopy in the important mid-IR region [2-5]. The application of cw and pulsed single frequency QC-DFB lasers to the sensitive detection of CH_4, N_2O, NO, C_2H_5OH (ethanol) and different isotopic species of H_2O in ambient air will be reported. In order to determine the ethanol concentration from its dense infrared spectrum, a new approach based on a linear correlation technique was applied.

A commercial multipass cell aligned for a 100 m optical path was used. The pressure in the cell was set to 20-40 Torr. A "zero-air" background subtraction technique [6] was also used to enhance the detection sensitivity to the ppb concentration level. Spectra of ambient air and a pollutant-free "zero air" were alternatively taken with the sequential subtraction of the zero-air signal from the ambient air signal. In some measurements, pure air with an addition of 5% CO_2 was used as a zero gas. The laser radiation was detected with a liquid nitrogen cooled photovoltaic MCT detector. The QC laser frequency was rapidly tuned with current at a 100 to 1000 Hz repetition rate with a variable duty cycle. In experiments with a near-room temperature pulsed QC laser, 7 to 10 ns current pulses were applied to the laser. Fast frequency tuning was obtained using a sub-threshold ramped current, as in Ref. 5. A pulsed QC laser shows a line broadening caused by frequency chirping due to the pulsed drive current. The narrowest laser linewidth obtained had a FWHM of 0.016 cm^{-1} (480 MHz).Frequency scans were typically over a 2 cm^{-1} range for cw and 0.25 cm^{-1} for pulsed operation. In a pulsed mode, longer continuous frequency scans were also achieved with the QC laser temperature tuning in -15°C to +15°C range (~0.09 cm^{-1}/°C).

Absorption spectra of ambient air obtained with cw and pulsed QC-based gas sensors will be reported. The best estimated sensitivity is 2.5 ppb for CH_4, 1.0 ppb for N_2O, 2 ppb for NO, 63 ppt for H_2O and 125 ppb for C_2H_5OH.

References

1. F. Capasso, C. Gmachl, A. Tredicucci, A. L. Hutchinson, D.L. Sivco, and A.Y. Cho, "High Performance Quantum Cascade Lasers", Optics & Photonics News **10**, 32-37 (1999)
2. A. A. Kosterev, R. F.Curl, F. K. Tittel, C. Gmachl, F. Capasso, D.L. Sivco, J.N. Baillargeon, A. L. Hutchinson, and A.Y. Cho, "Methane concentration and isotopic composition measurements with a mid-infrared quantum cascade laser", Opt Lett. **24**, 1762-1764 (1999)
3. B.A. Paldus, T.G. Spence, R.N. Zare, J. Oomens, F.J.M. Harren, D.H. Parker, C. Gmachl, F. Capasso, D.L. Sivco, J.N. Baillargeon, A.L. Hutchinson, and A.Y. Cho, "Photoacoustic spectroscopy using quantum-cascade lasers", Opt. Lett. **24**, 178-180 (1999)
4. S.W. Sharpe, J.F. Kelly, J.S. Hartman, C. Gmachl, F. Capasso, D.L. Sivco, J.N. Baillargeon, and A.Y. Cho, "High-resolution (Doppler-limited) spectroscopy using quantum-cascade distributed- feedback lasers", Opt. Lett. **23**, 1396-1398 (1998)
5. K. Namjou, S. Cai, E.A. Whittaker, J. Faist, C. Gmachl, F. Capasso, D.L. Sivco, and A.Y. Cho, "Sensitive absorption spectroscopy with a room-temperature distributed-feedback quantum-cascade laser", Opt. Lett. **23**, 219-221 (1997)
6. A. Fried, S. Sewell, B. Henry, B.P. Wert, T. Gilpin, and James R. Drummond, "Tunable diode laser absorption spectrometer for ground-based measurements of formaldehyde". J. Geophys. Res., **102**, 6253-6266 (1997)

Deconstructing Continuous Entanglement for Photon Localization

J.H. Eberly*
Rochester Theory Center for Optical Science and Engineering and Department of Physics and Astronomy,
University of Rochester, Rochester NY 14627 USA

Abstract: Two-photon emission in atomic cascade decay or in parametric down-conversion produces frequency-entangled continuum states. We will discuss how so-called Schmidt modes of the vacuum [1,2] discretize the mode space exactly (without imposing finite box boundary conditions), and give explicit examples. Among other things, the discretization allows an effective counting of the uncountably many continuous frequency modes, permits easy estimation of information content, and allows the determination that a single photon is localized in a specific space-time region without detecting it.

*Research partially supported by ARO-D and NSF

[1] H. Huang and J. H. Eberly, J. Mod. Opt., 40, 915 (1993), and 43, 1891 (1996).
[2] C.K. Law, I.A. Walmsley and J.H. Eberly (submitted, 1999)

Optimum distinction of nonorthogonal states in quantum mechanics: an optical realization

János A. Bergou[1,2], Mark Hillery[1], and Yuqing Sun[1]
[1]*Department of Physics, Hunter College of the City University of New York, 695 Park Avenue, New York, NY 10021, USA*
Telephone: +1-212-772-5254; FAX: +1-212-772-5390; E-mail: jbergou@shiva.hunter.cuny.edu
[2]*Institute of Physics, Janus Pannonius University, Ifjúság u. 6, H-7624 Pécs, Hungary*
Telephone/FAX: +3672-501-571; E-mail: bergou@fizika.jpte.hu
(April 5, 2000)

SUMMARY

Unambiguous distinction between nonorthogonal but linearly independent quantum states is one of the challenging problems in quantum information processing. In principle, the problem could be solved by mapping a set of nonorthogonal quantum states onto a set of orthogonal ones which then can be distinguished without error. Since unitary transformations are angle conserving, a mapping of this sort requires that nonunitary methods be employed. Such nonunitary transformations are offered by generalized measurements (Positive Operator-Valued Measurements, POVMs) [1]. In these measurements a probe is entangled to the system and the measurement is performed on the probe afterwards. A certain, prescribed, state of the probe is correlated to uniquely determined orthogonal states of the system for every possible nonorthogonal initial state of the system. The probe is found in this prescribed state with a probability that we might call the probability of success.

Quantum measurement theory predicts, however, that such nonunitary transformations will always have a certain probability of failure. For the discrimination of nonorthogonal states this failure probability corresponds to the probability that one gets inconclusive results from the detection of the probe. Therefore, the problem is to find the optimum solution that minimizes the average probability of failure. It has been proved that only linearly independent quantum states can be distinguished unambiguously, and to achieve optimum discrimination the set of the initial states should be mapped onto a linearly dependent set when inconclusive answers are obtained [2].

Here we show how to construct generalized interferometers (multiports) which implement nonunitary transformations on quantum systems. This is a generalization of our earlier work [3] which proposed an optical realization to optimally distinguish between two nonorthogonal states. First, we will show that single photon states can be used to represent an arbitrary number of nonorthogonal states at the input ports of an optical multiport while other input ports - the probe ports - are empty. Then, with measurements made by photon detectors placed at the output ports corresponding to the probe, we can realize the desired nonunitary transformation on the initial single photon states, provided an appropriate choice of the parameters the multiport (mirror transmission and reflection coefficients, phase shifts) is made [4]. The ensuing transformation, i. e. mapping of nonorthogonal input states to orthogonal output states, is an all optical realization of an optimal quantum measurement for distinguishing nonorthogonal states. Finally, we also discuss the feasibility of an interferometric experiment along these lines, using single photon femtosecond pulses detecting coincidence and anticoincidence counts between the probe and signal output ports.

This research was supported by the Office of Naval Research (Grant Number: N00014-92J-1233), by the Hungarian Science Research Fund (OTKA, Grant Number: T 030671) and by a grant from PSC-CUNY.

---

[1] A. Peres, *Quantum Theory: Concepts and Methods* (Dordrecht: Kluwer, Amsterdam, 1993), pp 282-5.
[2] A. Chefles, LANL Report, quant-ph/9807022.
[3] J. Bergou, M. Hillery, and Y. Sun, Non-unitary transformation in quantum mechanics: an optical realization, J. Mod. Opt., **47**, 487 (2000).
[4] J. Bergou, M. Hillery, and Y. Sun, Multiports and the optimal realizations of POVMs, in preparation.

Experiments with slow light

George R. Welch, Irina Novikova, Eugeny Mikhailov,
Vladimir L. Velichansky, Yuri Rostovtsev, Marlan O. Scully

A coherently prepared quantum system has many novel characteristics. Among the best known is electromagnitically induced transparency where the absorption of light resonant with an allowed transition is canceled by quantum interference. This phenomena has enabled distortion-free pulse propagation through optically thick media, lasing without inversion, and very efficient nonlinear optical processes such as four wave mixing.

Recently, experiments have shown that the very steep dispersion associated with such a coherently prepared system leads to an extreme reduction of optical group velocity. This very low group velocity can be made lower than the mean thermal speed of atoms in a vapor, which opens the possibility of bringing the speed of light to rest -- freezing the light.

We report on our experiments in Lambda-EIT systems, covering a range of topics -- from attempts to further slow group velocity with the thermal motion of the atoms to efficient four wave mixing and precision magnetometry.

DARK AND BRIGHT STATES OF THE COHERENTLY EXCITED ATOM

R.N. Shakhmuratov[1,4], A. Szabo[2], G. Kozyreff[3], R.Coussement[1], J.Odeurs[1] and P.Mandel[3]

[1] *Instituut voor Kern- en Stralingsfysica,*

Katholieke Universiteit Leuven,

Celestijnenlaan 200 D, B-3001 Leuven, Belgium

[2] *Institute for Microstructural Sciences, National Research Council of Canada,*

Ottawa, ON, K1A0R6, Canada

[3] *Optique Nonlinéaire Théorique, Université Libre de Bruxelles,*

Campus Plaine C. P. 231, B-1050 Bruxelles, Belgium

[4] *Kazan Physical-Technical Institute, Russian Academy of Sciences,*

10/7 Sibirsky trakt st., Kazan 420029 Russia

Abstract

We extend the concept of the coupled (C) and noncoupled (NC) states to describe a three-level atom interacting with two or three resonant fields. Depending on the number of fields and their detunings, particular states can be introduced. We call them bright (b) and dark (d) states. For some cases they coincide with the C and NC states. With the help of these states we reduce the analysis to the consideration of a two level system interacting with one effective field. Then a simple Bloch-vector model is applied to describe the evolution of the initially complicated system. Special attention is paid to the low frequency coherence excitation, nonadiabatic population transfer and population trapping.

Luigi Lugiato

Spatial quantum entanglement and optical images

Abstract.

The field of imaging has remained up to now confined in the domain of Classical Physics.

On the other hand, recent studies have pointed to the existence of relevant phenomena of quantum entanglement in space and of local squeezing in the light emitted in nonlinear optical processes. Such effects may become useful in the field of imaging, for example to increase the resolution of details, in the detection of edges and to achieve the noiseless amplification of faint optical images. This circumstance has given rise to the newly born field of Quantum Imaging. The talk will briefly mention also the possibility of applying these ideas to quantum cryptography and to realize the quantum teleportation of optical images.

Quantum Noise Effects in Strongly Driven Systems

R. P. O'Connell*
Department of Physics and Astronomy, Louisiana State University
Baton Rouge, LA 70803-4001

We have recently emphasized [1] that one of the most widely used tools in quantum optics, the Lax formula for two-time correlations, not only involves the weak coupling approximation but that it applies only for frequencies near a resonance frequency. Thus, it cannot incorporate quantum noise effects.
Whereas the Lax formula can treat many effects in quantum optics (such as the laser linewidth and resonance fluorescence) we point out examples (such as the temperature-dependent shift of spectral lines due to coupling with an ambient blackbody radiation field, tunneling in a non-Markoffian dissipative environment or the equation of motion of a radiating electron in a form which is free of runaway solutions [2]) where it cannot be applied. In such cases, we show that one must use the fluctuation-dissipation theorem or the quantum Langevin
equation generalized to incorporate memory effects.

[1]G. W. Ford, R. F. O'Connell, Optics Comm., M. 0. Scully Festschrift, in press.

[2]G. W. Ford and R. F. O'Connell, Phys. Rev. A 57, 3112 (1998).

Phone : (225) 388-6848
FAX: (225) 388-5855
e-mail: rfoc@rouge.phys.lsu.edu

THE PROBLEM OF LOCALIZING PHOTONS

Alexander S. Shumovsky and Alexander A. Klyachko

Faculty of Science, Bilkent University, Bilkent, 06533 Ankara, Turkey
e-mail: shumo@fen.bilkent.edu.tr

In spite of a great success of quantum electrodynamics and quantum optics, there still are some conceptual problems (e.g., see [1]). One of them is the problem of localizing photons, which has attracted a great deal of interest (see discussions in [1,2]). The point is that the photons are usually described in terms of the creation and destruction operators defined in the whole space at once, while the detection by absorption of a photon by a detecting device is always a local process [3].

To avoid this discrepancy, we propose an approach based on the investigation of spatial structure of the electromagnetic vacuum state. We show that in the presence of a quantum localized source (atom or molecule, for example) the spatial inhomogeneity of the vacuum state takes place. Then, the action of global photon operators on this inhomogeneous vacuum gives rise to the local excitations of the radiation field described by the local representation of the Weyl-Heisenberg algebra [4]. These local "quasi-photons" have sense of the photon densities. They can be used to describe the local quantum properties of the radiation field such as the number statistics and polarization.

The scheme of quantum generation-detection process based on the use of the outgoing and incoming spherical waves of photons is discussed. The application of the Aaronov-Bohm type optical measurements [5] in the near and intermediate zone measurements is proposed.

---

1. M.O. Scully and M.S. Zubairy *Quantum Optics* (Cambridge Univ. Press, New York, 1997)

2. L. Mandel and E. Wolf *Optical Coherence and Quantum Optics* (Cambridge Univ. Press, 1995)

3. L. Mandel *Phys. Rev. Lett.* 144, 1071 (1961)

4. A.S. Shumovsly and A.A. Klyachko *Los-Alamos Archive,* quant-ph/9911087 (1999)

5. I.O. Kulik and A.S. Shumovsky, *Appl. Phys. Lett.* 69, 2779 (1996)

Quantum Interference, Coherent Control and Laser Isotope Separation

Edward A. Manykin
Nonlinear Optics Department, RRC "Kurchatov Institute" (Russia)
Address: Kurchatov sq. 1, Moscow 123182, RUSSIA.
Fax: 7 (095) 196 59 73 Phone: 7 (095) 196 91 07 E-mail: edmany@isssph.kiae.ru

The quantum interference of atomic transition under multiphoton resonances is now turning in one of fast developing field of modern optics since early theoretical proposals of Afanas'ev and Manykin [Sov. Phys. JETP, **25**, 828 (1967)], and subsequent experimental study of Drabovich et. al. [Bulletin of the Acad. Scien. USSA, **53**, 164 (1989)]. Here I will review some of recent works on phase control quantum mechanical interference between optical transitions, atomic coherences, laser control, and four-wave mixing under multiphoton resonances.

By considering simple model systems I demonstrate suppression of the multiphoton absorption, and related effect of absolute transparency. I show how the quantum interference could be controled by changing the intensity and frequency detuning of control laser. I describe how that scheme enables enhance or suppress efficiency of resonant nonlinear optical transitions and especially multiphoton ionization.

Our work on two-photon and three-photon resonances utilizes the schemes studied by Ce Chen, Yi-Yian Yin, and D.S. Elliott [Phys. Rev. Lett. **64**, 507 (1990)]. We present new approach to study the two-photon excitation together with step by step transition into atomic vapors. We calculate enhancement and suppression factor of the several orders in the output signals under a variety of conditions. This approach also enables us to study others related issues. I will show the influence of phase matching on nonlinear optical resonant processes.

Finally I will present the recent results on the coherent control of laser isotope separation at very small isotopical shifts.

Quantum interference and nonlinear optics

J.E. Sipe

Department of Physics, University of Toronto

For excitation frequencies above the band gap of a semiconductor or insulator, qualitatively new nonlinear optical phenomena appear. Shift currents arise during excitation due to the difference in the centre of charge in valence and conduction bands. As well, macroscopic currents can actually be injected involving average electron velocities of hundreds of kilometers per second. The latter effect involves electrons and holes acquiring momentum from the crystal lattice, and can be understood as arising from a quantum interference between the different pathways leading to absorption. These phenomena appear both in crystals that lack centre-of-inversion symmetry and in those that do not, but in qualitatively different ways. Recent theoretical and experimental work will be reviewed, as well as new studies of the extension of these coherent control techniques to surface physics and the injection of spin currents.

Ultrafast Electron Dynamics in Metal Nanoparticles

C. Voisin, D. Christofilos, N. Del Fatti, and F. Vallée

Laboratoire d'Optique Quantique du CNRS.
Ecole Polytechnique, 91128 Palaiseau cedex, France.
email: vallee@leonardo.polytechnique.fr

Reduction of the size of a material to a nanometric scale leads to drastic modifications of its physical properties that evolve from those of a solid to those of a few atom cluster. In metallic systems, the conduction electron scattering processes play a central role in these properties and study of their alteration by the confinement is thus of both fundamental and technological interests. Time resolved femtosecond techniques are powerful tools for such investigations in bulk material. We will discuss here the application of these techniques to the study of the electron interaction processes and of their modification by the confinement in metal nanoparticles.

Experimental investigations take advantage of the connection between the system optical properties and the electron distribution. Using a femtosecond pulse, energy is selectively injected in the electron gas and its relaxation dynamics followed by monitoring the sample transmission with a probe pulse. Depending on the excitation and probing conditions, different electron-interaction processes can be studied. We will focus here on the results obtained in a model system formed by silver nanoparticles embedded in a dielectric matrix. The relatively simple band structure of silver permit a selective probing of the internal electron thermalization dynamics (i.e., of the electron-electron interactions) and of electron-lattice thermalization (i.e., of the electron-phonon coupling). Both of these effects are accelerated in small metal nanospheres (radius smaller than about 5 nm) demonstrating confinement induced increase of the electron-electron and electron-phonon interactions, in agreement with a simple model that phenomenologically introduces electron environment modification by the particle surface.

` Abstract LPHYS'2000.docNonlinear Gyrotropy
Photoinduced Faraday rotation in semimagnetic semiconductor nanostructures

R. Frey(1), M. Haddad(1), R. André(2), J. Cibert(2), C. Flytzanis(1)

1 - Laboratoire d'Optique Quantique du C.N.R.S., Ecole Polytechnique, 91128 Palaiseau cedex, France
2 - Laboratoire de Spectrométrie Physique, Université Joseph Fourier Grenoble I and C.N.R.S.
BP 87, 38102 Saint Martin d'Hères cedesx, France

ABSTRACT

The strongly coupled photon-charge-spin system encompasses many important features that are of fundamental interest and also show promise for applications where the polarization state control of the light is an issue. This is the case for instance in unidirectional control or shielding of optical signal transfer.

Here we summarize the recent observation of giant photoinduced Faraday rotation in semimagnetic semiconductor nanostructures where the effective magnetooptic coupling is strikingly enhanced by spin exchange. This was achieved with moderate light and magnetic field intensities in 1μm thick samples (multiple quantum wells) close to the excitonic resonance and can amount to several tens of degrees and in fact can cancel the linear Faraday rotation there. The underlying mechanisms are discussed and some features are used to study spin dynamics in these materials.

We have also evidenced photoinduced magnetization in the absence of any external static magnetic field when using circularly polarized beams. Different regimes have been studied. The effect can be of relevance for the study of the magnetopolaron and spin dynamics and its extension to other materials can be envisaged.

We also report results of the linear regime of the transmission and reflection from magnetooptic microcavities containing a single quantum well of semimagnetic semiconductor.

Femtosecond Laser Spectroscopy of underdoped $YBa_2Cu_3O_{7-\delta}$: Marginal or Two-Dimensional Fermi Liquid?

Yu.E. Lozovik[a] , A.L. Dobryakov[a], S.A. Kovalenko[b], V. M. Farztdinov[a,b], S.P.Merkulova[a] , N.P. Ernsting[b]

[a]*Institute of Spectroscopy, Russian Academy of Sciences Moscow region, Troitsk 142092* Russia

e-mail: lozovik@isan.troitsk.ru ; Fax:+7 095 334 08 81

[b]*Institut für Physikalische und Theoretische Chemie, Humbold - Universität zu Berlin, D-10117 Berlin, Germany*

The method for probing Fermi liquid (FL) *vs* non-Fermi liquid (NFL) behavior in the normal state of high T_c underdoped oxide-superconductor $YBa_2Cu_3O_{7-\delta}$ by femtosecond pump-supercontinuum probe spectroscopy is presented. The method is based on the determination of the spectral dependence of nonequilibrium charge carriers relaxation rate $\gamma(\omega_{probe})$ in a wide spectral range of probing, $\hbar\omega_{probe}$ = 1.6 – 3.2 eV. It is shown that the relaxation rate sharply decreases for the optical transitions in the vicinity of the Fermi level E_F, the position of the rate minimum pointing the location of E_F. The selective determination of the relaxation rates for different groups of electrons for given spectral region is discussed. The probe energy dependence of the relaxation rate around the minimum gives unique information on the quasiparticles damping rate near the Fermi level and hence can resolve the FL versus NFL behavior. Deviations from the FL behavior in $YBa_2Cu_3O_{7-\delta}$ -- linear instead of quadratic energy dependence of the relaxation rate-- is observed. Possible interpretation is presented. The result is compared with ordinary metals with weak electron correlations.

New method of measuring of electron- phonon interaction parameter through relaxation rate energy dependence revealed by pump-supercontinuum probe technique is demonstrated. Coherent phonon generation by ultrashort laser pulse is discussed.

ARTIFICIAL DISPERSION OF INHOMOGENEOUS AND NON - STATIONARY MEDIA - EXACTLY SOLVABLE MODELS

G.Petite and A.Shvartsburg*
Lab. des Solides Irradies, Ecole Polytechnique, 91128, France
e- mail address: petite@hp1sesi.polytechnique.fr
* CDBUI, Russ. Acad. Sci., Moscow, 117342, Butlerov St. 15

This research is centered on the development of physical fundamentals and mathematical basis of a new general approach, effective for the series of wave problems for both inhomogeneous and non-stationary media. This approach is based on the special transformations of Maxwell equations, reducing these equations with coordinate (time) - dependent coefficients to one equation with some constant coefficients. This equation describes the EM fields in terms of habitual harmonic waves, travelling in some new mathematical space, determined by the transformed variables, meanwhile the field in a physical space can be unharmonic and even non - periodic. Reflection and refraction of EM waves, incidenting on the interface of inhomogeneous (non-stationary) media, can be examined by means of Fourier presentations in this new space, using phase path length (Lagrange variables) instead of coordinates (time).

The wide classes of flexible models of these media, containing four free parameters, are elaborated, and the exact analytical solutions, presenting the refracted EM waves via the elementary functions in a new space, are shown. The following results were obtained due to this approach:

1. The non - local dispersion and new cut-off frequencies, arising due to continuous coordinate- dependent distribution of dielectric susceptibility, are examined. A controlled formation of the areas of both positive and negative inhomogeneity - induced dispersion of an inhomogeneous dielectric can be provided in an arbitrary spectral range via an appropriate choise of the dielectric susceptibility spatial profile. Unlike the natural dispersion of materials, where a strong dispersion nearby the resonances is accompanied by an enhanced absorption, the artificial inhomogeneity-induced dispersion can be formed in a spectral range, far from the absorption bands of media.

An analogous artificial dispersion and cut-off frequencies in the non-stationary dielectrics is considered.

2. Generalized Fresnel formulae, visualizing the influence of first and second derivatives of coordinate (time)- dependent dielectric susceptibility with respect to coordinate (time) on the material's reflectivity, are obtained.

3. The broadband antireflection and transmittivity bands of thin dielectric films in visible and IR ranges, sensitive to the inhomogeneous distributions of dielectric susceptibility, are illustrated.

Cavity Quantum Electrodynamics with Trapped Ions

H. Walther

Sektion Physik der Universität München and
Max-Planck-Institut für Quantenoptik
85748 Garching, Fed. Rep. of Germany
Tel. +49 +89 32905-704, Fax +49 +89 32905-710
e-mail: herbert.walther@mpq.mpg.de

Abstract:

Single ions trapped and laser cooled provide ideal objects for high resolution spectroscopy and frequency standards. For the latter purpose we are investigating the $5s^2\ ^1S_0 \rightarrow 5s5p\ ^3P_0$ transition of In^+. With a natural linewidth of only 0.8 Hz this resonance offers very high resolution and is highly immune to frequency shifts due to external electromagnetic fields, because it connects two levels with vanishing electronic magnetic momenta. The wavelength of this clock transition is 236.5 nm and is technically very convenient, since it coincides with the fourth harmonic of the 946 nm Nd:YAG laser line. So this intrinsically frequency stable solid-state laser can be used to excite the transition. For laser cooling and fluorescence detection of the indium ion the $5s^2\ ^1S_0 \rightarrow 5s5p\ ^3P_1$ transition at 230.6 nm can be employed. The use of the relatively narrow intercombination line for laser cooling allows us to study optical sideband cooling in the strong binding regime, where the oscillation frequencies of the ion in the trap (around 1 MHz) are larger than the optical linewidth of 360 kHz. In this parameter range laser cooling is possible to the quantum ground state of the vibrational motion of an ion in the trap. The same low temperature was obtained with sideband cooling of a small Coulomb crystal consisting of two ions, creating an interesting new quantum few-particle system, which can be the basis for quantum computing.

It has been shown recently that it is also possible to use a single trapped ion as medium for a laser. Such device is suitable to demonstrate typical quantum phenomena not present in a normal laser system. Furthermore, this laser allows to study phenomena resulting from the overlap of light and particle waves.

In the talk also measurements of the spectrum of a single trapped Mg^+ ion will be discussed. By using a heterodyne technique to detect the fluorescent light we have obtained an unprecedented resolution of a small fraction of a Hz. This narrow bandwidth has allowed us to spectroscopically isolate the elastically scattered component of fluorescence, which is coherent with the laser field. In a Hanbury-Brown and Twiss experiment the same light shows nonclassical antibunching. The system thus demonstrates complementarity with wave behaviour in the case of heterodyne detection and particle behaviour when photons are counted. There is the hope that squeezing of the fluorescent light can be investigated with the setup in the near future.

Real-time Manipulation of Single, Strongly Coupled Atoms.

C. J. Hood, T. W. Lynn, D. W. Vernooy, J. Ye, A. C. Doherty, H. C. Nagerl,
D. M. Stamper-Kurn and H. J. Kimble

Norman Bridge Laboratory of Physics 12-33, California Institute of Technology
Pasadena, CA 91125
phone (626) 395 8343, fax (626) 793 9506, email: hood@its.caltech.edu

Recent experiments are discussed which demonstrate real-time trapping and monitoring of single atoms within an optical resonator.
In one experiment, a classical standing-wave far off-resonant trap (FORT) provides the trapping potential. The trapping beam, which is resonant with the cavity mode, is triggered on with the arrival of a single atom, detected by cavity QED coupling to a transmitted probe field. In the second experiment the cavity QED interaction provides the trapping force. This is possible because the single photon atom-field interaction energy is larger than the kinetic energy of the laser-cooled atoms. Again, the potential is triggered by detection of a single atom entering the cavity mode.

Being in a regime of strong coupling enables high signal-to-noise ratio at single photon field strengths for monitoring atomic position, a situation which would not be possible for an equivalent field in free space. This capability is employed to investigate the motion of atoms trapped within the resonator. Variations in transmission of the cavity field are used to
reconstruct the trajectories of single atoms, thereby realizing a new form of microscopy - the Atom Cavity Microscope.
The resulting trajectories show atoms radially orbiting the center of the cavity-mode, localized near an antinode of the standing-wave. By relating the potential depth and secular frequencies to the diffusion rate, it is found that a very large atom-field coupling strength is required to observe this type of near-conservative motion.

On the Polarization Properties of One-Atom Micromasers

V.A. Reshetov* and I.V. Yevseyev**

* Department of Physics, Togliatti Pedagogical Institute, Bul'v. Koroleva 13, Togliatti, 445859 Russia
** Department of Theoretical Physics, Moscow State Engineering Physics Institute, Kashirskoe Shosse 31, Moscow, 115409 Russia; E-mail: yevseyev@theor.mephi.msk.su

The Jaynes-Cummings model describing the interaction of a single linearly-polarized mode of the quantized electromagnetic field with an isolated two-level atom is generalized to the case of atomic levels degenerate in the projections of the angular momenta on the quantization axis, which is a usual case in the experiments. This generalization, like the original model, obtains the explicit analytical solution. The model is applied to calculate the dependence of the cavity field characteristics on the angle between the polarization of the cavity field mode and that of the laser excitation pulse in the experiment with one-atom micromaser. It is shown that the polarization of the excitation pulse may be varied to govern the cavity field parameters, for example, to increase the average number of the photons saturating the cavity field or to switch the photon statistics from sub- to super-Poissonian.

Quantum Optics with "Slow" and "Trapped" Light

Mikhail D. Lukin

Electromagnetically Induced Transparency allows one to coherently control propagation of light pulses in optically dense ensembles of atoms. It can result, for instance, in pulse propagation with very slow group velocities and in enhanced nonlinear optical effects. Furthermore, it is possible to "trap" the pulses in such a media by adiabatically reducing the group velocity to zero. In this process the quantum state of the light is copied, coherently and reversible, onto metastable states of matter.

Possible applications of these techniques for quantum information processing as well as recent experimental results will be discussed.

Diode-pumped ultrashort pulse lasers

E.Wintner, I.T.Sorokina, E.Sorokin
Photonics Institute
University of Technology Vienna
Gusshausstrasse 27/387
A-1040 Wien, Austria
email: ernst.wintner@tuwien.ac.at

The generation of ultrashort pulses is an ever growing challenging field of laser science. Pulse durations steadily have gone down reaching nearly the ultimate limit of single cycles. Recently, other parameters than pulse duration came into the focus of attention like tunability around various wavelengths, the emission of very high average powers and finally, the most important aspect towards practical applicability, i.e. the employment of direct diode pumping.

In general, two groups of solid-state laser media suitable for diode pumping can be distinguished: i) Transition metal ion doped laser crystals like Cr^{3+}:LISAF,Cr^{3+}:LICAF, Cr^{3+}:LiSGAF and others out of the group of colquiriites; Cr^{3+}:forsterite, :alexandrite, :emerald, :garnet; Cr^{4+}:YAG; Co^{2+}:MgF_2; Cr^{2+}:ZnSe and other II-VI host crystals; other dopants in similar media like Fe^{2+}, Ti^{2+}, Co^{2+} in CdS, CdSe, CdMnTe etc. Such broad-band laser media allow very short pulse durations in the fs-regime down to around 10 fs spanning a wide wavelength range from ~0,5 μm to 5 μm. ii) If other laser parameters should be optimised like efficiency or average power other media are the materials of choice at the expense of somewhat longer pulse durations in the regime of 100 fs to ~ 1ps. These are rare earth doped laser media like Nd^{3+}, Tm^{3+}, Ho^{3+}, Er^{3+} in various crystals like YAG, YLF, vanadate and others or in different glasses. If a good compromise for bandwidth and hence pulse duration and crystalline host properties like heat conduction should be achieved mixed garnets like GSAG:YSGG and related ones have proven to be successful. For high average powers and efficiency Yb^{3+} recently gained high attention, e.g. Yb^{3+}:YAG, :S-FAP or Yb^{3+}:Y_2O_3, ,:Lu_2O_3, :Sc_2O_3 (sesquioxides). An Yb^{3+}:YAG thin disk laser passively modelocked via SESAMs (semiconductor saturable absorber mirrors) holds the record for average power of 16.2 W at τ_p = 730 fs.

There is a large variety of new applications for ultrashort pulses becoming technologically and economically relevant if simple, compact and cheap solutions of such lasers become available. Details will be reported in the presentation.

Enhancement of Spin Superradiance by Hyperfine Interactions

V.I. Yukalov and E.P. Yukalova

Bogolubov Laboratory of Theoretical Physics
Joint Institute for Nuclear Research, Dubna 141980, Russia

and

Department of Computational Physics
Laboratory of Computing Techniques and Automation
Joint Institute for Nuclear Research, Dubna 141980, Russia

Superradiant spin dynamics in ferromagnets is considered with nonlinearity due to three factors: (i) the sample is prepared in a strongly nonequilibrium state, so that evolution equations cannot be linearized as would be admissible for spin motion not too far from equilibrium, (ii) the system considered consists of interacting electron and nuclear spins coupled with each other via hyperfine forces, and (iii) the sample is inserted into a coil of a resonant electric circuit producing a resonator feedback field. Due to these nonlinearities, coherent motion of spins can develop, resulting in their ultrafast relaxation. A complete analysis of mechanisms triggering such a coherent motion is presented. This type of ultrafast coherent relaxation can be used for studying intrinsic properties of magnetic materials.

Near IR CW laser-diode-pumped Raman fiber lasers

I.A. Bufetov, E.M.Dianov, A.M.Prokhorov
General Physics Institute, Russian Academy of Sciences,

State of the art, tendencies of development and main applications of CW Raman fiber lasers with the out put power of 1- 10 W will be presented.

Nonlinear optical models with multiparameter bifurcations

E.V. Degtiarev (LaSen Inc., Las Cruces, New Mexico); A.V. Larichev(ILC-Moscow State University): I.P. Nikolaev (ILC-Moscow State University); V. Wataghin (INFN-Turin University)

Abstract

We discuss several ways of designing optical systems with multi-parameter bifurcation points. The idea is to introduce a nonlinear coupling between two dynamical variables in the basic Kerr-slice-with-optical-feedback model. One such system, based on a Liquid Crystal Light Valve, was shown to have a Takens-Bogdanov(TB) codimension-two bifurcation point. Nonlinear effects due to the interaction between stationary and oscillatory instabilities near the TB point were predicted theoretically and later found experimentally. Another system is based on coupled polarization nonlinearities in polymer films. Preliminary theoretical results will be presented.

FIVE-WAVE-MIXING PROCESS $\omega_b = \omega_1 + \omega_1 + \omega_1 - \omega_2$ FOR STUDYING CHIRAL MOLECULES IN SOLUTION

V. A Makarov*, S. M. Donskoi

Physics Department and International Laser Center
M. V. Lomonosov Moscow State University
Vorobievy Gory, Moscow 119899, Russia
*Fax: (095) 939-3113, Phone: (095) 939-1225, *E-mail: makarov@wavlab.ilc.msu.su*

We advance a theory of wave generation at a frequency ω_b in the bulk of an isotropic gyrotropic medium. Such wave arises in the five-wave-mixing process $\omega_b = \omega_1 + \omega_1 + \omega_1 - \omega_2$ underlying the bioCARS spectroscopic technique [1]. This technique is designed for studying complex organic compounds (sugars, albumens etc.) in solution. As a rule, molecules of such substances are chiral (i. e. they possess neither centers nor planes of inversion), as contrasted to more simple molecules of a solvent. Therefore, the solvent does not have local optical susceptibilities of any even order, and hence does not make a spurious contribution to the signal at the frequency ω_b.

We have investigated problem of the bioCARS-signal generation by two non-collinear Gaussian beams of fundamental radiation with frequencies $\omega_{1,2}$. The calculations are performed in the case where the characteristic dimensions of the beams intersection area are much smaller than the diffraction lengths of the interacting waves. Allowance was made for the linear optical activity of the medium. We have obtained analytical expressions for the spatial distribution and the total power of the wave at the frequency ω_b. The spatial dispersion of the optical response of the medium was established to have a strong effect on the shape of the phase-synchronism curves, as well as to lead to the signal wave becoming elliptically polarized even in the absence of a circular optical dichroism. It was also revealed that the dependence of the signal power on the directions of the pumping-waves polarization planes changes significantly with the increase in the optical activity of the medium. On the basis of experimental data available [2] we have estimated the magnitude of the fourth-order optical susceptibility of an arabinose aqueous solution.

1. N. I. Koroteev. *Biospectroscopy*, **1**, 341 (1995).
2. A. P. Shkurinov, A. V. Dubrovskii, N. I. Koroteev. *Phys. Rev. Lett.*, **70**, 1085 (1993).

TWO-COLOR OPTICAL SUPERRADINCE IN THE OPTICALLY DENSE $LaF_3:Pr^{3+}$ CRYSTAL

V.A.Zuikov, A.A.Kalachev, V.V.Samartsev, A.M.Shegeda
Kazan Physical and Technical Institute of RAS
10/7 Sibirsky Trakt Str., Kazan, 420029, Tatarstan, Russia
phone: (8432)763681; fax: (8432)765075; e-mail: samartsev@dionis.kfti.kcn.ru

The results of the detailed experimental studies of the two-color optical superradiance in the $LaF_3:Pr^{3+}$ crystal are presented. The peculiarities of the nonlinear and coherent interaction of the 10-ns pulses with the praseodymium ions in LaF_3 optically dense samples are investigated. The influence of such laser pulse is carried out on the wavelength 477.7 nm, corresponding to $^3H_4$—$^3P_0$ transition with a resonant absorption coefficient α=4.7 cm^{-1} and the length of samples L=0.8 cm at liquid helium temperatures. Our experiments reveal the existence of superradiant pulses simultaneously emitted through two energy transitions: $^3P_0$—$^3H_4(0)$ (λ=477.7 nm) and $^3P_0$—$^3H_6$ (λ=606 nm) with delay times t=12÷15 ns and 20÷30 ns respectively. Since $\alpha L > 1$, the pumping pulse and the superradiance's signals are propagating in the optically dense resonant medium. Intriguing specific features of the propagation of these pulses were observed in experiments where the carrier frequency and the power of pumping pulse were varied. These specific features can be explained in terms of the solution of the three-level problem within the framework of the Bloch-Maxwell equations.

High Intensity Laser-Beam Propagation in the Earth Atmosphere

Roland Sauerbrey[1)], S. Niedermeier[1),2)], Y.-B. André[3)], M. Franco[3)], J. Kasparian[1),2)], D. Mondelain[2)], A. Mysyrowicz[3)], B. Prade[3)], M. Rodriguez[4)], S. Tzortzakis[3)], H. Wille[4)], J.-P. Wolf[2)], L. Wöste[4)], J. Yu[2)]

" **Teramobile**", Joint CNRS/DFG Project, Berlin, Jena, Lyon, Palaiseau

[1)] Institute for Optics and Quantum Electronics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, GERMANY Phone: +49 3641 947200 Fax:+49 3641 947202, e-mail: sauerbrey@qe.physik.uni-jena.de

[2)] Universite Claude Bernard Lyon 1, Laboratoire de Spectrometrie Ionique et Moleculaire,(LASIM, UMR NRS 5579), 69622 Villeurbonne Cedex, FRANCE

[3)] Laboratoire d'Optique Appliquée, CNRS UMR 7639, École Polytechnique – ENSTA, 91761 Palaiseau, FRANCE

[4)] Prof. Ludger Wöste, Freie Universität Berlin, Institut für Experimentalphysik, Arnimallee 14, 14195 Berlin, GERMANY

Abstract

Femtosecond laser beams with powers in the terawatt range propagate over long distances in the atmosphere and emit a white light continuum. New investigations show that the white light laser channels are electrically conducting, their spectrum extends into infrared to at least 4 μm and that the whight light emission is anisotropic. Applications of these phenomenon to LIDAR are discussed.

Clean Molecular Fluorescence and a new type of LIDAR

S. L. Chin, A. Talebpour, Mahmoud Abdel-Fattah
Dept. of Physics and
Center for Optics, Photonics and Laser (COPL)
Laval University
Quebec, Qc G1K 7P4
Canada.

Abstract:

Clean fluorescence from the interaction of intense femtosecond Ti-sapphire laser pulses with molecules at up to atmospheric pressure was observed without the interference of plasma continuum. The physics of the process and the prospect of applying this technique to a new type of LIDAR will be discussed.

Self-Guided Propagation Of Intense Femtosecond Laser Pulses Through Atmosphere

A. Mysyrowicz, S. Tzortzakis, Y-B. André, M. Franco, B. Prade

Laboratoire d'Optique Appliquée, Centre National de la Recherche Scientifique, Ecole Nationale Supérieure de Techniques Avancées – Ecole Polytechnique, Chemin de la Huniére, F-91761 Palaiseau Cedex, France

Intense femtosecond laser pulses launched in atmosphere self-organise into filaments which can subsist over long distances. We discuss the physical origin of this effect . Experimental results concerning IR and UV pulse filamentation are compared to numerical simulations. Application of filaments to the formation of a conductive air channel are described.

Optically Turbulent Femtosecond Light Strings

J.V. Moloney
Arizona Center for Mathematical Sciences
University of Arizona, Tucson 85721

High power IR or UV wavelength femtosecond-duration laser pulses offer exciting opportunities for creating novel probes of atmospheric phenomena. The underlying physics of the nonlinear interactions going on within these intense pulses is complex and represents a major theoretical and computational challenge. The pioneering experiment by a group in Jena, Germany using a 2.6 TW 100 fs pulsed source has led to an explosive growth in the experimental and theoretical study of this problem. In recent work, we identified the basic mechanism by which the laser pulse forms a self-induced waveguide in air. Rather than form a stationary waveguide, a narrow pulse develops a sequence of critical self-focusing events with each being limited by optical breakdown of air. This we term "dynamic spatial replenishment".

A major challenge that remains is how a much broader pulse such as that used in the Jena experiment can sustain itself over many kilometers of propagation through the atmosphere. Taking the critical self-focusing power in air as 2 GW, the Jena pulse contains on the order of 1000 critical powers. Our recent work has established that the broad pulse breaks up via a classical modulational instability into many coexisting light foci, followed by dynamic spatial replenishment. Each critical self-focusing event leaves a narrow plasma spike in its wake. The end result is that a complex supercontinuum light source is created together with an array of meter long narrow plasma filaments that recombine after the pulse has departed. My talk will emphasize the collective action of these intense light foci and plasma filaments. In addition, I will discuss how polarization effects can modify the self-induced nonlinear waveguide.

Femtosecond pulse propagation in air: Beyond the slowly varying envelope approximation

N. Aközbek and C. M. Bowden
US Army Aviation and Missile Command, Weapons Sciences Directorate MRDEC
Huntsville, Alabama, USA 35898-5000
Email: nakozbek@mciworld.com

A. Talebpour and S. L. Chin
Centre d'Optique, Photonique et Laser and Département de Physique, Université Laval
Quebec City, Quebec G1K 7P4 Canada

Abstract

We study the propagation of femtosecond pulse propagation in air in the presence of multiphoton ionization. The effect of higher-order terms arising from going beyond the slowly varying envelope approximation of the underlying propagation equation will be presented. Our model also includes linear dispersion, delayed nonlinear response. In addition, defocusing effects arising from higher-order terms in the nonresonant nonlinear polarization is discussed. Our results agree well with experimental results.

Ultra-fast cooling of electronic subsystem of ultra-thin Ni films: studying by coherent four-photon picosecond spectroscopy

V.V. Shuvalov, V.M. Petnikova, K.V. Rudenko

M.V. Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119899, Russia

Phone: +7(095)9395035, Fax: +7(095)9393113, E-Mail: vsh@vsh.phys.msu.su

We are going to present here our recent results in studying of ultra-fast (with duration less than 20 ps) relaxation processes in ultra-thin (with thickness in the range 5 - 25 nm) Ni films on K8 glass and ZrO_2 substrates. Ultra-thin continuous Ni films have been investigated by two methods of coherent four-photon picosecond (20 ps pulse duration) spectroscopy - the biharmonic pumping technique (BP), the degenerate four-photon spectroscopy (DFPS), and transient gratings (TG) technique. Specific resonant features have been found in the self-diffraction efficiency as a function of pumping components' frequency detuning (BP) and wavelength (DFPS). By the model, which takes into account a real electronic structure of Ni, its quantum-size renormalization and spin splitting, main inter-band and intra-band relaxation processes, saturation and selection rules for electronic transitions, interpretation of the obtained results has been performed. BP results have been explained in terms of the "paramagnetic" phase of Ni films whereas DFPS ones have been interpreted in terms of Ni "ferromagnetic" phase with execution of all corresponding selection rules.

It has been shown that due to the sample spatially inhomogeneous excitation, an ultra-fast spatial redistribution of free carriers and generation of resonant acoustic wave at the corresponding (to the dynamic grating) spatial frequency might happen. It is why, in spite of the electronic subsystem temperature Θ_e ever increases due to the film picosecond excitation, the pumping components' frequency detuning determines a rate of Θ_e increase through changing the efficiency of energy exchange between the sample electronic and phonon subsystems. In the DFPS case, Θ_e can not considerably exceed the lattice temperature Θ_p and rich the Curie point Θ_c. Specific oscillations have been observed in the probe pulse diffraction efficiency as a function of time-delay of the probe pulse in relation to pumping components (TG). In the BP case, pumping components (due to their frequency detuning) can "write" only rapidly running interference patterns. In this case, the acoustic wave can not be efficiently generated and energy excess of the electronic subsystem can not be quickly passed to the lattice. Due to a small heat capacity of the electronic subsystem, Θ_e can significantly exceed Θ_p and overcome Θ_c. It means that Θ_e is a key parameter that determines energy splitting of spin sub-bands. The inter-band polarization relaxation time $T_2 = 200 \div 250$ fs has been determined.

In conclusion, we would like to underline a top-priority importance of a combined analysis of the data, obtained by two different spectroscopic techniques (BP, DFPS, and TG) in the same experimental conditions, in frames of the same rather realistic theoretical model. Such an analysis has enabled us to make some very interesting and important conclusions.

Ablation rate enhancement by combination of picosecond and nanosecond laser pulse trains

Klimentov S.M., Garnov S.V., Kononenko T.V., Konov V.I., Pivovarov P.A., and Dausinger F.*

General Physics Institute of the Russian Academy of Sciences
Vavilov str.38, 117942 Moscow, Russia
tel. (095) 132 8146, fax. (095) 234 9022
e-mail: kliment@kapella.gpi.ru
*University of Stuttgart
Pfaffenwaldring 43, 70569 Stuttgart, Germany
fax. (0711) 685 6842

Combination of pulses of different duration and intensity within one laser shot is an important resort for improvement of ablation efficiency. Indeed, the initial pulses of a succession are able to modify ablation conditions for the following portions of radiation providing residual heat in the ablated area and increased absorptivity of the material, which, generally speaking, results in lowering of the ablation threshold. While, a train of short laser pulses at the end of the succession can promote of the ablated material removal.

Following this approach, we developed a Nd:YAG laser system delivering combination of picosecond and nanosecond pulse trains during single pumping pulse and applied the temporally profiled radiation to drilling and micromachining of steel, ceramics and CVD diamond. This combination turned out especially beneficial for deep channel formation, demonstrating from one to two orders of magnitude enhancement of ablation rates compared to conventional pico- and nanosecond pulsed ablation at the same energy density. In experiments, we positioned samples at an input window of an integrating sphere to define correctly ablation rates and to reveal dynamics of the through hole formation. The photometric sphere also enabled evaluation of transportation losses for radiation transmitted through the channels created in different materials and allowed estimation of plasma shielding effects.

The transmission losses were found to be high and polarization dependent, which effected shape of the output crater. Possible mechanisms of the phenomena observed are discussed. Prospective of high rate material microstructuring were illustrated by high aspect ratio cutting and trepanning in ceramics and CVD diamond.

Seminar 2
Strong-Field Phenomena

Monday, July 17, 2000

Chair: P. Agostini (France) **Session 2.1**

11.00-11.40 R.R. Freeman and R. Snavely, M. Key et al. (Davis, CA, USA)
The generation of intense, high energy collimated proton beams from non-linear processes generated by a short pulse high intensity laser

11.40-12.00 D.B. Milosevic, W. Becker, R. Kopold and W. Sandner (Berlin, Germany)
High-harmonic generation by bicromatic bicircular laser field

12.00-12.20 J. Peatross, I. Kohl, N. Terry, S. Voronov, Q. Wang (Provo, UT, USA)
Manipulation of high harmonic generation using counter-propagating light

12.20-12.40 A. Scrinzi, M. Geissler, and T. Brabec (Vienna, Austria)
Techniques for attosecond pulse detection and the observation of electronic motion

12.40-13.00 A. Tarasevich, C. Dietrich, A. Orisch, and D. von der Linde (Essen, Germany)
High efficient spatially coherent emission of high order harmonics from solid surfaces

13.00-14.00 Lunch

Chair: S.P. Goreslavsky (Russia) **Session 2.2**

14.00-14.20 V. Veniard, R. Taieb and A. Maquet (Paris, France)
A simple model for harmonic generation from atomic cluster

14.20-14.40 D.F. Zaretsky (Moscow, Russia)
Amplification of high harmonics in an atomic jet and a fiber

14.40-15.00 A. Jaron, J. Z. Kaminski and F. Ehlotzky (Warsaw, Poland; Innsbruck, Austria)
Laser-assisted radiative recombination and X-ray generation

15.00-15.20 V.P. Krainov (Moscow, Russia)
Inverse Stimulated Bremsstrahlung of Slow Electrons under Coulomb Scattering

15.20-15.40 H.-J. Kull and L. Plagne (Aachen, Germany)
Quantum-Mechanical Dielectric Model and Classical Particle Simulations of Photoabsorption in Strong Laser Fields

15.40-16.00 G. Ferrante, M. Zarcone (Palermo, Italy)
Magnetic field phenomena due to anisotropic bremsstrahlung plasma heating

16.00-16.30 Coffee Break

Chair: V.P. Krainov (Russia) **Session 2.3**

16.30-17.10 Ch. Cornaggia, L. Quaglia, and Ph. Hering (Gif-Sur-Yvette, France)
Molecular multi-electron excitation in strong femtosecond laser fields

17.10-17.30 M.Yu. Ivanov, D. Villeneuve, M. Spanner, S. Aseyev, and P. Corkum (Ottawa, Canada)
Strong Field Molecular Optics

17.30-17.50 A.D. Bandrauk, H.Z. Lu, I. Kawata, H. Kono (Sherbooke, Canada; Sendai, Japan)
Charge resonance enchanced ionization revisited –CRFI – role of ionic states as doorway states

17.50-18.10 E. Charron, D. Stibbe and A. Suzor-Weiner (Paris, France)
Molecular dynamics and control in ultrashort laser pulses

18.10-18.30 M. Brewczyk (Warsaw, Poland)
The role of dissipation in multielectron dissociative ionization of small molecules

18.30-18.50 S. Bivona, R. Burlon, C. Leone (Palermo, Italy)
Multicolor Detachment of a Negative Ion in the Presence of a Static Magnetic Field

18.50-19.10 R. Daniele, A. Di Piazza, E. Fiordilino and F. Morales (Palermo, Italy)
High Order Harmonic Generation of an Atom in the Presence of a Strong Laser Pulse

Tuesday, July 18, 2000

Chair: M.Yu. Ivanov (Canada) — Session 2.4

11.00-11.30 P. Lambropoulos (Garching, Germany)
Ab Initio Theory of Double Photoionization

11.30-11.55 B. Piraux and G.L. Kamta (Louvain-la-Neuve, Belgium)
Theoretical study of the interaction of a two-active electron system with an ultrashort laser pulse

11.55-12.15 R. Kopold and W. Becker (Berlin, Germany)
Differential rates for nonsequential double ionization in intense laser fields

12.15-12.40 F.H.M. Faisal and A. Becker (Bielefeld, Germany)
Role of correlation and final-state Volkov dressing on the dynamics of laser induced double ionization

12.40-13.00 H. Rottke, C. Trump, M. Wittmann, G. Korn, W. Sandner (Berlin, Germany)
Correlation in strong field atomic double ionization: The momentum distribution of the photoelectrons

13.00-14.30 Lunch

Chair: M.V. Fedorov (Russia) — Session 2.5

14.30-15.10 W. Sandner (Berlin, Germany)
Multi-electron ionization dynamics in strong laser fields

15.10-15.30 O.V. Tikhonova, A.M. Popov, E.A. Volkova (Moscow, Russia)
Rescattering model and double electron ionization of atoms in a strong laser field

15.30-15.50 H. Bachau, E. Cormier, and R. Hasbani (Talence, France)
Resonant and non-resonant ionization of helium by XUV ultrashort and intense laser pulses

15.50-16.30 M. Stehle and G. Gerber (Würzburg, Germany)
Optimization of calcium atom double ionization with phase-shaped femtosecond laser pulses

16.30-17.00 Coffee Break

Chair: W. Becker (Germany) — Session 2.6

17.00-17.40 Ch. Joachain (Brussels, Belgium)
Relativistic effects in laser-atom interactions

17.40-18.00 E. Lenz, M. Dörr, and W. Sandner (Berlin, Germany)
Relativistic Ionization Dynamics in a 1D Model

18.00-18.20 U. Eichmann, M. Dammasch, M. Kalashnikov and W. Sandner (Berlin, Germany)
Ionization dynamics at relativistic laser intensities

18.20-18.40 G. Duchateau, E. Cormier and R. Gayet (Talence, France)
Ionisation of hydrogen and alkaline atoms by intense femtosecond and sub-femtosecond laser pulses

18.40-19.00 Q. Su and R. Grobe (Normal, IL, USA)
Numerical solution of Dirac equation and its applications in intense laser physics

19.00-19.20 L.F. DiMauro and B. Sheehy (Upton, NY, USA)
Strong Field Physics in a Scaled Interaction

19.20-19.40 M. Fifirig and A. Cionga (Bucharest, Romania)
Helicity dependent angular distributions in two color ionization of hydrogen-like atoms

Wednesday, July 19, 2000

Chair: A.M. Popov (Russia) — Session 2.7

11.00-11.40 A. Czirjak, R. Kopold, W. Becker, M. Kleber, W.P. Schleich (Ulm, Germany)
The Wigner function for tunneling in a uniform static electric field

11.40-12.00 S.P. Goreslavsky (Moscow, Russia)
The generalized Keldysh model in the tunneling regime

12.00-12.20 K.T. Taylor, J.S. Parker, L.R. Moore and D. Dundas (Belfast, UK)
Accurate calculations for laser-driven helium in full-dimensionality

Wednesday, July 19, 2000

Chair: A.M. Popov (Russia)
Session 2.7

11.00-11.40 A. Czirjak, R. Kopold, W. Becker, M. Kleber, W.P. Schleich (Ulm, Germany)
The Wigner function for tunneling in a uniform static electric field

11.40-12.00 S.P. Goreslavsky (Moscow, Russia)
The generalized Keldysh model in the tunneling regime

12.00-12.20 K.T. Taylor, J.S. Parker, L.R. Moore and D. Dundas (Belfast, UK)
Accurate calculations for laser-driven helium in full-dimensionality

12.20-12.40 F. Quere, S. Guizard and Ph. Martin (Palaiseau, France)
Optical breakdown in dielectric solids

12.40-13.00 S. Varro (Budapest, Hungary)
The effect of laser-induced oscillating double layers on nonlinear photoemission at metal surfaces

13.00-14.30 Lunch

Thursday, July 20, 2000

Chair: B. Piraux (Belgium)
Session 2.8

11.00-11.30 A.M. Popov, O.V. Tikhonova, and E.A. Volkova (Moscow, Russia)
Computer experiments on atomic stabilization in a strong laser field

11.30-12.00 M. Gavrila (Cambridge, US & Amsterdam, The Netherlands)
Stabilization of atoms in ultra-strong laser fields, a reassessment

12.00-12.20 M.Yu. Ryabikin and A.M. Sergeev (Nizhny Novgorod, Russia)
Lorentz force effect in strong-field atomic stabilization

12.20-12.40 M. Dörr and R.M. Potvliege (Berlin, Germany; Durham, UK)
Stabilization in photodetachment by ultrashort pulses

12.40-13.00 L. Roso and J.R. Vazquez de Aldana (Salamanca, Spain)
Atomic photoionization beyond the dipole approximation

13.00-14.30 Lunch

Chair: J.H. Eberly (USA)
Session 2.9

14.30-15.10 Ph. Bucksbaum (Ann Arbor, MI, USA)
Coherent control of quantum dynamics in strong laser fields

15.10-15.30 E.A. Shapiro (Moscow, Russia)
Patterns of localization of Rydberg wave packets

15.30-15.50 M.V. Fedorov and N.P. Poluektov (Moscow, Russia)
Photoionization of Rydberg atoms in interference stabilization regime: influence of initial distribution of atomic population

15.50-16.10 G.G. Paulus F. Grasbon, and H. Walther (Garching, Germany)
Quantum interference effects in above-threshold ionization

16.10-16.30 J.H. Posthumus, L.J. Frasinski and K. Codling (Garching, Germany; Reading, UK)
Experimental evidence for dynamic Raman processes on the rising and falling edges of intense laser pulses

16.30-17.00 Coffee Break

17.00-19.00 INTENSE SHORT LASER PULSE PROPAGATION IN AIR
(Joint Session with the Modern Trends in Laser Physics Seminar)

Chair: C. Bowden (USA) **Session 1.10 & 2.10**

17.00-17.30 R. Sauerbrey, S. Niedermeier, J. Kasparian (Jena, Germany), D. Mondelain, J.-P. Wolf, J. Yu (Villeurbonne, France), Y.-B. André, M. Franco, A. Mysyrowicz, B. Prade, S. Tzortzakis (Palaiseau, France), M. Rodriguez, H. Wille, L. Wöste (Berlin, Germany)
High intensity laser-beam propagation in the earth atmosphere

17.30-17.55 S.L. Chin, A. Talebpour, Mahmoud Abdel-Fattah (Quebec, Canada)
Clean Molecular Fluorescence and a new type of LIDAR

17.55-18.20 A. Mysyrowicz, S. Tzortzakis, Y-B. André, M. Franco, B. Prade (Palaiseau, France)
Self-guided propagation of intense femtosecond laser pulses through atmosphere

18.20-18.40 J.V. Moloney (Tucson, USA)
Optically turbulent femtosecond light strings

18.40-19.00 N. Aközbek and C.M. Bowden (Huntsville, USA), A. Talebpour and S.L. Chin (Quebec, Canada)
Femtosecond pulse propagation in air: Beyond the slowly varying envelope approximation

Friday, July 21, 2000

Chair: A. Maquet (France) **Session 2.11**

11.00-11.20 A. Saveliev, S.A. Gavrilov, D.M. Golishnikov, V.M. Gordienko, P.M. Mikheev, A.A. Shashkov, T.V. Vlasov, and R.V. Volkov (Moscow, Russia)
Energetic particles generation in nanostructured solids

11.20-11.40 K. Ishikawa and T. Blenski (Gif-sur-Yvette, France)
Rare gas cluster explosion in a strong laser field

11.40-12.00 E. Suraud, P.G. Reinhard (Toulouse, France)
Clusters in intense laser pulses

12.00-12.20 N.L. Manakov (Voronezh, Russia)
Circular and elliptic dichroisms in laser interactions with unpolarized targets

12.20-12.40 N. Narozhny and M.S. Fofanov (Moscow, Russia)
Acceleration of free electrons by a high-intensity laser pulse

12.40-13.00 H.R. Reiss, A. Shabaev, and H. Wang (Washington, DC, USA)
New results on strong-field-accelerated nuclear beta decay

THE GENERATION OF INTENSE, HIGH ENERGY, COLLIMATED PROTON BEAMS FROM NON-LINEAR PROCESSES GENERATED BY A SHORT PULSE HIGH INTENSITY LASER

R.R. FREEMAN

DEPARTMENT OF APPLIED SCIENCE,
UNIVERSITY OF CALIFORNIA
DAVIS, CA

AND

R. SNAVELY, M. KEY et al.,

LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CA

We have observed an intense, collimated beam of high energy protons emitted normal to the rear surface of thin solid targets irradiated by a laser with nearly 1 petawatt of power and a peak intensity of 3×10^{20} W/ cm^2. Up to 12% of the incident energy of the laser is converted into the production of approximately 10^{13} protons of energy greater than 10 MeV. The proton beam is observed to be highly collimated, with the higher energy particles (~60 MeV) being tightly focused in the center. Several induced nuclear processes, such as neutron production in Be targets, were also observed. This highly non-linear process represents a rather unexpected result of non-linear processes at laser intensities of such magnitude that virtually all classical and perturbation models are at a complete loss to explain the data. This talk will discuss the current theoretical understanding of the highly relativistic phenomena envolved, as well as speculate on applications of the collimated proton source.

HIGH-HARMONIC GENERATION BY BICHROMATIC BICIRCULAR LASER FIELD

D. B. MILOŠEVIĆ†, W. BECKER, R. KOPOLD and W. SANDNER

Max-Born-Institut, Max-Born-Strasse 2a, Berlin 12489, Germany
e-mail: milos@mbi-berlin.de
phone: +49-(0)30-6392-1325, fax: +49-(0)30-6392-1309

An efficient method is investigated for the generation of circularly polarized high-order harmonics by a bichromatic laser field whose two components with frequencies ω and 2ω are circularly polarized in the same plane, but rotate in opposite directions [1]. The generation of intense harmonics by such a driving-field configuration was already confirmed by a previous experiment [2]. With the help of both a semiclassical three-step model as well as a saddle-point analysis, the mechanism of harmonic generation in this case is elucidated and the plateau structure of the harmonic response and their cutoffs are established. Optimization of both the cutoff frequency and the harmonic efficiency with respect to the intensity ratio of the two components of the driving field is discussed. The electron trajectories responsible for the emission of particular harmonics are identified. Unlike the case of a linearly polarized driving field, they have a nonzero start velocity. Depending on the (unknown) saturation intensity for the bichromatic field with counter-rotating polarizations, this scheme might be of practical interest not only because of the circular polarization of the produced harmonics, but also because of their production efficiency. The possibility of EUV harmonic generation around 13 nm in connection with the development of extreme ultraviolet litography is discussed. The temporal structure of high-harmonic generation and its potential for the emission of attosecond pulse trains are explored. A special emphasize will be on unusual nonlinear polarization of these pulse trains.

1. D. B. Milošević, W. Becker, and R. Kopold, Phys. Rev. A (to be published).
2. H. Eichmann, A. Egbert, S. Nolte, C. Momma, B. Wellegehausen, W. Becker, S. Long, and J. K. McIver, Phys. Rev. A **51**, R3414 (1995).

†On leave from: Faculty of Sciences, Department of Physics, University of Sarajevo, Zmaja od Bosne 35, 71000 Sarajevo, Bosnia-Herzegovina, and supported in part by the Alexander von Humboldt Foundation.

MANIPULATION OF HIGH HARMONIC GENERATION USING COUNTER-PROPAGATING LIGHT

J. Peatross, I. Kohl, N. Terry, S. Voronov, Q. Wang
Dept. of Physics and Astronomy
Brigham Young University
ESC Box 67, Provo, UT 84602-4667, USA
Tel. (801) 378-5043; E-mail: peat@byu.edu

We have for the first time demonstrated strong interruption of the high-order harmonic generation process in an intense laser focus by introducing relatively weak counter propagating light. This was experimentally achieved for harmonic orders ranging in the twenties generated by a 30fs, 0.15mJ laser pulse focused with f/40 optics into a ~0.5mm jet of argon. The counter propagating light was prepared with similar beam characteristics except for being chirped to ~1ps, resulting in an intensity ~30 times less. Although the counter-propagating light is too weak in itself to produce high harmonics or even to induce ionization (of significance), it creates standing amplitude and phase modulations on the main generating pulse, resulting in microscopic phase mismatches and the disruption of harmonic emission.

We will report on preliminary attempts to surgically suppress the harmonic generation process in selected zones of the focus with undesirable phase. By tailoring a sequence of counter-propagating light pulses, a versatile quasi-phasematching scheme can be achieved along the z-dimension of the focus. The eventual goal of this research is to apply the technique to very high harmonic orders which are the most vulnerable to phase mismatches, making possible dramatic enhancements to the emission through a quasi phasematching over many coherence lengths. The technique may also make more accessible the study of high harmonic generation from ions which suffer from severe phase mismatches owing to free electrons.

Techniques for attosecond pulse detection and the observation of electronic quantum motion

Armin Scrinzi, Michael Geissler, and Thomas Brabec

Institut für Photonik, Vienna University of Technology, Gusshausstr. 27/387, A-1040 Vienna, Austria

phone: +43-1-58801-38714, fax: +43-1-58801-38799, e-mail: scrinzi@tuwien.ac.at

The observed spectral width of xuv harmonics generated by intense femtosecond laser pulses suggests that attosecond pulses may already have been produced. However, direct observation of an attosecond pulse duration has not been possible so far. Here we propose a method to cross–correlate the electric field of a strong laser pulse with an xuv attosecond pulse. The basic time scale for the measurement is the 1/2 the optical period of the laser. The non-linear process which correlates the laser electric field with the xuv-attosecond pulse is one-photon ionization in the presence of the electric field.

An outline of the attosecond cross correlation (ACC) technique is as follows (Fig. 1): An as-pulse and an intense laser pulse are simultaneously focused into a singly ionized He plasma The photon energy of the xuv-pulse must be smaller than the ionization potential. The peak electric field strength of the laser pulse is chosen large enough to suppress the Coulomb barrier below the 2p state of the He^+ ion. The as-pulse generates a maximum number of He^{++} ions, when it coincides with a peak of the laser electric field, while He^{++} production is lowest, when the as-pulse is located at a node of the laser pulse. The modulation of the He^{++} yield with the relative delay between the two pulses gives a measure of the as-pulse duration.

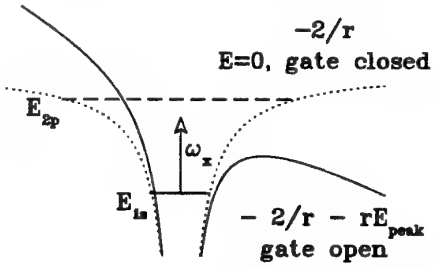


Fig. 1. Cross correlation between a laser electric field and an attosecond xuv-pulse.

Numerical simulations show that xuv pulse durations between 1/2 and 1/10 of the optical cycle of the laser pulse can be resolved. For realistic pulse energies a He^{++} yield of the order 10^{-4} per He^+ ion can be obtained, which is easily measurable. At an xuv pulse duration of 1/10 of the laser optical cycle, modulation of the He^{++} yield is as strong as 70 %. The technique is insensitive to time jitters caused by fluctuations of the laser pulse parameters, including the carrier phase, since the same laser pulse is used for both, as-pulse generation and cross-correlation.

Once attosecond pulses are available, the basic idea of pump-probe experiments can be extended into a time domain, where the electronic motion is purely quantum mechanical. We investigate the time-resolved observation of electronic motion in a superposition of the 1s and of the metastable 2s state of atomic hydrogen. Due to the difference in binding energies, the relative phase between the 1s and 2s states oscillates with a period of 405 as leading to corresponding oscillations of the electron density near the nucleus. To follow the electronic motion, the atom is exposed to a xuv pulse with duration < 400 as which causes photoionization. Since ionization strongly depends on the electron density near the nucleus, the photoelectron yield is modulated by the 1s-2s relative phase oscillations. We propose an experimental setup and discuss methods for the production of the 1s-2s superposition state and for the energy-selective detection of the photoelectrons.

High Efficient Spatially Coherent Emission of High Order Harmonics from Solid Surfaces

A. Tarasevitch, C. Dietrich, A. Orisch, and D. von der Linde

Institut fuer Laser- und Plasmaphysik, University of Essen, D-45117 Essen, Germany
Phone: +49 201 183 2565, Fax:+49 201 183 2120
e-mail: tar@ilp.physik.uni-essen.de

Generation of optical harmonics of high order is one of the most promising tools for generating short wavelength coherent radiation. In noble gases harmonics up to about the 300th order have been produced [1]. A different approach is high order harmonic generation (HOHG) by femtosecond laser pulses in specular reflection from solid targets. According to the theoretical predictions at relativistic intensities ($I \geq 10^{18}W/cm^2$) the number of harmonics and the conversion efficiency is strongly enhanced [2]. However, laser pulses of very high contrast are required. A prepulse or a slowly rising leading front of the pump pulse lead to premature ionization of the target and destruction of its initial density profile. That lead to substantial spectral broadening and a very wide angular distribution, not expected for the generation of reflected harmonics from a planar interface [3].

In this paper we report on the results of HOHG experiments in which high contrast ratio femtosecond laser pulses up to relativistic intensities were used. The conversion efficiency of 10^6 – 10^7 for 10-15 harmonic orders was measured. It has been demonstrated that the harmonic emission is nearly diffraction limited.

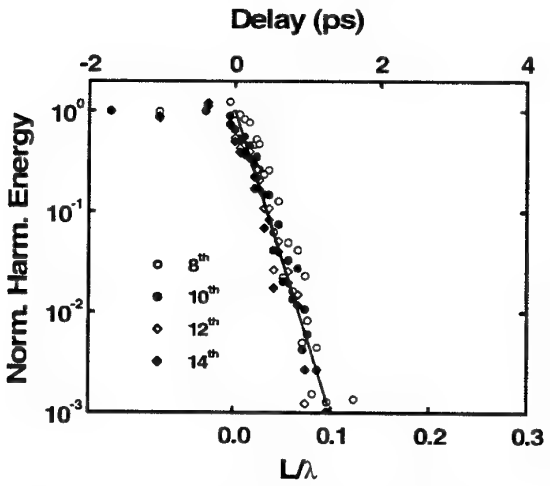


Fig. 1. Energy of different harmonics as a function of the time delay and plasma scale length. Solid line: exp(-L/0.015λ)

Pump-probe experiments were carried out in order to investigate the dependence of HOHG efficiency and coherence on the plasma scale length. A plasma was created on the surface of the target by a first, relatively weak laser pulse (~$10^{14}W/cm^2$). A second pulse (~$10^{17}W/cm^2$) with an adjustable time delay with respect to the first pulse was used to produce harmonics. The efficiency of HOHG drops very quickly with increasing plasma scale length (Fig.1), apparently much faster than predicted by PIC simulations[4]. In contradiction with the PIC simulations we also do not observe a certain "optimum" scale length for HOHG during the expansion of the plasma.

1. Z. Chang, A. Rundquist, H. Wang, M. M. Murnane, and H. C. Kapteyn, Phys. Rev. Lett. **79**, 2967 (1997); Ch. Spielmann, N. H. Burnett, S. Sartania, et al., Science **278**, 661 (1997).
2. R. Lichters, J. Meyer-ter-Vehn, and A. Pukhov, Phys. Plasmas **3**, 3425 (1996); Gibbon, Phys. Rev. Lett. **76**, 50 (1996); D. von der Linde and K. Rzhazhewski, Appl. Phys. B 63, 499 (1996)
3. P. A. Norreys, M. Zepf, S. Moustaizis, et al., Phys. Rev. Lett. **76**, 1832 (1996); J. Zhang, M. Zepf, P. A. Norreys, et al., Phys. Rev. A **54**, 1597 (1996).
4. R. Lichters, J. Meyer-ter-Vehn, Inst. Phys. Conf. Ser. **154**, 221 (1997); M. Zepf, G. D. Tsakiris, G. Pretzler, et al., Phys. Rev. A **58**, R5253 (1998).

A simple model for harmonic generation from atomic cluster

Valérie Véniard, Richard Taïeb and Alfred Maquet

Laboratoire de Chimie Physique-Matière et Rayonnement

(UMR 7614 du CNRS)

Université Pierre et Marie Curie

11, Rue Pierre et Marie Curie 75231 Paris Cedex 05 FRANCE.

Phone: 33-1-44-27-66-31 Fax: 33-1-44-27-62-26 email: vv@ccr.jussieu.fr

High order harmonic generation by atoms irradiated by a strong infrared laser appears as a source of coherent XUV radiation with interesting coherence and brightness properties. It was proposed recently that atomic clusters can also be a source of short-wavelength radiation, providing in some cases harmonic yields higher than those produced by equivalent atomic targets [1]. However, no general picture has emerged about the relative efficiency of clusters as compared to atoms.

We have addressed the question of the response of an atomic cluster to an intense laser pulse by numerically solving the Time-Dependent Schrödinger Equation for a simplified one-dimensional system [2]. New results, concerning more realistic models, will be presented, including propagation effects and/or exchange potentials.

[1] T. D. Donnelly *et al.*, Phys. Rev. Lett. **76**, 2472 (1996); J. W. G. Tisch *et al.*, J. Phys. B: At. Mol. Opt. Phys. **30**, L709 (1997). [2] V. Véniard, R. Taïeb and A. Maquet, Phys. Rev. A **60**, 3952 (1999)

Amplification of high harmonics in an atomic jet and a fiber.

D.F.Zaretsky
Russian Research Center « Kurchatov Institute » Moscow, 123182, Russia
E-mail: zaretskyeirnp.kiae.ru

April 17, 2000

The problem of amplification of a high-order harmonic pulse (the weak probe wave) when it passes through the interaction volume containing the atomic medium in the presence of an intense laser field (the strong pump wave) is considered. Amplification is the net result of the competition between simulated emission and absorption of high-harmonic photons. In such situation the gain of the probe wave is proportional to the difference between the probability w_e, for the emission of a probe-wave quantum and the probability w_a, of its absorption by the atoms in the interaction volume [11,

$$G \propto \Delta w = w_e - w_a.$$

In the present work the probabilities of the simulated emission and absorption were calculated in the frame of the strong field approximation [2]. The influence of the ion recoil and the phase matching effect were taken into account. The final expression for the gain was rewritten to number (per laser pulse) of spontaneous quanta of sth harmonic N, *[1,* 3] and evaluated for the experimental data on N, from [4] for the cases of the atomic jet and the hollow-core fiber. The parameters of the atomic beam (fiber) and the pump wave are taken from the experirnent [41 too.

The gain was investigated as a function of the atomic concentration on the axis of the jet or in the center of the fiber. An optimal conditions for the amplification of the probe wave corresponds to relatively high atomic concentration then the number of spontaneous quanta decreases smoothly. At the density where the number N, assumes its maximum, the gain is equal to zero [3]. The optimal value of the gain in the case of fiber (G°_{max} = 0, 17) is substantially larger than in the jet *(*G°_{max} = 0, 04). Therefore, high-harmonic amplification should be investigated in an optical fiber rather than in an atomic jet.

Acknowledgrnents. We are grateful to the Deutsche Forschungsgemeinschaft (grant no. 436 RUS 113/536/0) and to the Russian Foundation for Basic Research (grant no. 99-02-04021) for partial financial support.

References

[1] D.F. Zaretskii, E.A. Nersesov, JETP 88 (1999) 895; E.A. Nersesov, D.F. Zaretskii, Laser Phys. 9 481 1999.

[2] W. Becker, A. Lohr, M. Kleber, M. Lewenstein, Phys. Rev. A 56 645 1997.

[3] E.A.Nersesov, S.V.Popruzhenko, D.F.Zaretsky, W. Becker Optics Communications (submitted).

[4] E. Constant, D. Garzella, P. Breger, E. Mével, Ch. Dorrer, C. Le Blanc, F. Salin, P. Agostini, Phys. Rev. Lett. 82 1668 1999.

Laser-assisted radiative recombination and X-ray generation

A. Jaron[1], J. Z. Kaminsky[1] and F. Ehlotzky[2]

Institute of Theoretical Physics, Warsaw University,

Hoza 69, PL 00-681 Warsaw, Poland

Tel +48-22-6283031 , Fax +48-22-6219475, E-mail: jaron@fuw.edu.pl, jkam@fuw.edu.pl

Institute for Theoretical Physies, University of Innsbruck, Technikerstrasse 25,

A-6020, Innsbruck, Austria

Tel +43-512-507-6214, Fax +43-512-507-2964, E-mail: l@ritz.EhlotzkyLâuibk.ac.at

The process of laser assisted recombination is considered in the context of harmonic generation and coherent X-ray production [1]. Very promising conditions for X-ray generation by means of laser field induced electron-ion recombination can be met in the Farkas and Horvàth experiment [2]. In this contribution we propose an approach, which is applicable both to gaseous and solid targets. The process of recombination is treated in the framework of the inverse Keldysh model in which the ingoing electron is described either by a Gordon-Volkov wave or by a Coulomb-Volkov solution with conclusion that even for higher energies of the impinging electrons visible Coulomb effects are observed. These Coulomb effects are discussed in connection to analogous effects studied for multiphoton ionisation and high harmonic generation [3, 4]. The equivalence of the two models for a short-range interaction is shown and diseussed.

The rates of the generated X-ray field and the energy range of its spectrum are obtained. The maximum photon energy that can be achieved via considered process is given by $\hbar\omega_X = E_{\bar{p}} + U_p + |E_B| + 2\sqrt{2U_p E_{\bar{p}}}$, with E_p being the kinetic energy of the ingoing electron, U_p, the ponderomotive energy and E_B the binding energy.

The differential power spectrum calculated as a function of the emitted X- ray photon energy for fixed electron energy exhibits plateau centered around $\Delta\omega_x = E_p + Up + |E_B|$, the width of which is equal to $\Delta\omega_X = 4\sqrt{2U_p E_{\bar{p}}}$ and increases with intensity of the laser beam while its maximum value slightly decreases with intensity. The power spectrum attains maximum values at the edges of the plateau.

Simple and intuitive model considered here allows for the discussion of the energy conversion efficiency for the X-ray production and permits to recognize the most favorable conditions for generation of X-rays. Results presented here are in agreement with results of another paper on laser-assisted radiative recombination [5].

References

[1] A. Jaron, J. Z. Kaminski and F. Ehlotzky, Phys. Rev. A **61,** 23404 (2000). [2] Gy. Farkas and Z. Gy. Horvàth, Opt. Commun. **21,** 408 (1977).

[3] J. Z. Kaminski, A. Jaron and F. Ehlotzky, Phys. Rev. A **53,** 1756 (1996);

A. Jaron, J. Z. Kaminski and F. Ehlotzky, Opt. Commun. **163,** 115 (1999).

[4] J. Z. Kaminski and F. Ehlotzky, Phys. Rev. A **54,** 3678 (1996).

[5] M. Yu. Kuchiev and V.N. Ostrovsky, Phys. Rev. A **61,** 33414 (2000).

9th International Workshop on Laser Physics (LPHYS'2000)
Seminar: Strong-Field Phenomena
July, 2000; Bordeaux, France

Inverse Stimulated Bremsstrahlung of Slow Electrons under Coulomb Scattering

V.P. Krainov
Moscow Institute of Physics and Technology,
141700 Dolgoprudny, Moscow Region, Russia; e-mail: krainov@cyberax.ru

Summary

A simple new analytic expression has been obtained for the rate of inverse stimulated bremsstrahlung of slow electrons scattered by the Coulomb charge Ze. The initial and final electron energies are assumed to be small compared to the Rydberg energy $mZ^2e^4/\hbar^2$. Weak linearly polarized field of frequency ω is considered, and only one-photon emission and absorption of the light are taken into account. High frequency ($\omega >> mv^3/Ze^2$) and low frequency ($\omega << mv^3/Ze^2$) limits are considered (v is the electron velocity). Both the quantum cases $\hbar\omega \sim p^2$, $\hbar\omega > p^2$ and the classical limit $\hbar\omega << p^2$ are considered (p is the electron momentum). The rate is averaged over the direction of the final electron momentum and over the angle between the light polarization and the direction of the initial electron momentum. It was found that in both laser frequency limits the rate of one-photon absorption is larger than the rate of one-photon emission, analogously to the well known opposite Born limit of rapid electrons [1]. Therefore, the energy of a slow electron increases with time (inverse stimulated bremsstrahlung). The rate of energy gain by slow electrons decreases with increasing laser frequency ω and does not contain the Coulomb logarithm [2]:

$$\frac{dE}{dt} = \frac{2\pi^2 Z^2 n_i \varepsilon^2}{15 \cdot 3^{5/6} \omega^2 p} \left(\frac{2}{Z\omega} \right)^{2/3} \frac{\Gamma(1/3)}{\Gamma(2/3)}.$$

Here n_i is the concentration of the Coulomb centers, ε is the amplitude of the laser field strength. The atomic system of units has been used here. This expression is also valid for $\hbar\omega > p^2$. The rates are averaged over Maxwell distribution of electrons. It was also found that the energy gain in the Born limit (rapid electrons) coincides with the energy gain for slow electrons if $\omega << mv^3/Ze^2$. The rates of electron-ion collisions are discussed in various limits. The obtained results can be also used for the derivation of the absorption of the laser radiation in cluster plasma [3].

References

1. Fedorov M V 1997 *Atomic and Free Electrons in a Strong Laser Field* (Singapore: World Scientific)
2. Krainov V P 2000 *J. Phys. B* **33** N8
3. Ditmire T et al 1996 *Phys. Rev.* A **53** 3379

Quantum-Mechanical Dielectric Model and Classical Particle Simulations of Photoabsorption in Strong Laser Fields

H.-J. Kull and L. Plagne

Institut für Theoretische Physik A
Rheinisch-Westfälische Technische Hochschule
D-52056 Aachen, Germany

Phone +49-241-8906 182, FAX +49-241-8888 188, Email kull@ilt.fhg.de

Inverse Bremsstrahlung photoabsorption in plasmas is commonly studied within the framework of the classical dielectric theory. This theory, based on work by Dawson and Oberman[1], can describe the nonlinear behavior of the collision frequency in strong fields[2] in close agreement with previous asymptotic results[3] and numerical results from classicle particle simulations[4].

In the present work, the dielectric theory is re-derived quantum-mechanically based on the first-order Born approximation. The quantum-mechanical result for the electron-ion collision frequency is found to agree with the classical result if the classical plasma dielectric function is replaced by the quantum-mechanical Lindhard function. Consequences of this substitution for large wavenumbers and for plasma temperatures lower than the ponderomotive potential will be discussed.

In addition, the collision frequency is calculated in the classical framework for a regularized soft-core Coulomb potential both by the dielectric theory and by numerical particle simulations. Choosing the same regularization of the Coulomb potential in both treatments, the results can be directly compared with each other and the accuracy of the dielectric approach can be quantitatively estimated.

References

[1] J. Dawson and C. Oberman, Phys. Fluids **5**, 517 (1962).

[2] C.D. Decker, W.B. Mori and J.M. Dawson, Phys. Plasmas **1**, 4043 (1994).

[3] P. Silin, Sov. Phys. JETP **20**, 1510 (1965).

[4] S. Pfalzner and P. Gibbon Phys. Rev. E **57**, 4698 (1998).

Magnetic Field Phenomena due to Anisotropic Bremsstrahlung Plasma Heating

G.Ferrante , M. Zarcone

Istituto Nazionale di Fisica della Materia and Dipartimento di Fisica e Tecnologie Relative, Viale delle Scienze, 90128 Palermo, Italy

S.A. Uryupin

P.N. Lebedev Physical Institute, Leninsky pr. 53, 117924, Moscow, Russia

The theory of the linear stage of the Weibel instability growth due to anisotropic heating of electrons undergoing inverse bremsstrahlung absorption of high frequency electromagnetic radiation is reported. The possibility is shown of a significant amplification of spontaneous magnetic fields for both the cases of circularly and linearly polarized high frequency radiation. Numerical calculations and comparisons are reported for a wide range of the process parameters, covering the cases of weak and strong high-frequency radiation fields. Among others, if the linearly polarized field is strong, the magnetic field amplification for typical conditions is found to be less significant as compared to the case of strong circularly polarized field. The reverse result is found for the case of weak linearly and circularly fields.

Molecular multi-electron excitation in strong femtosecond laser fields

C. Cornaggia, L. Quaglia, and Ph. Hering

CEA Saclay, Division des Sciences de la Matière

Service des Photons, Atomes, et Molécules, Bât. 522

F-91 191 GIF-SUR-YVETTE, FRANCE

Tél : (33) 1 69 08 96 65 Fax : (33) 1 69 08 90 63

E-mail : cornaggia@drecam.cea.fr

Multi-electron excitation in strong laser fields can only be studied through the multi-fragmentation of the system *i.e.* multiple ionization in atoms, and multiple ionization and Coulomb explosion in molecules. These processes are of fundamental interest for the correlated dynamics of the active electrons, and might present some applications for XUV radiation sources in particular for specific inversion diagrams for light amplification.

Two experimental methods are used to study these processes using femtosecond laser pulses at $\lambda = 800$ nm in the $10^{13} - 10^{17}$ W/cm^2 laser intensity range. The first method is aimed to study the multi-ionization efficiency and to compare the corresponding ion yields with single active electron sequential single ionization rates. The experimental work involves time-of-flight mass spectrometry, with a complete determination of the fragmentation channels associated to the molecular multiple ionization. Non-sequential double ionization of neutral molecules and singly charged molecular ions are observed for diatomic molecules such as N_2 and polyatomic molecules such as CO_2 or C_2H_2 at low laser intensities, where the precursor species are not completely ionized by the intense laser field.

The second method is based on fluorescence studies, and is aimed to identify excited states of transient multi-charged molecular ions. Indeed, the internal energy of these ions remains largely unknown, since the kinetic energy releases of the corresponding multi-fragmentation channels does not allow a complete determination of this internal energy. The fluorescence signals from the multi-charged fragments show unambiguously the existence of transient excited multi-charged molecules. Several detection methods will be presented due to the low efficiency of photon detection in comparison with ion detection. In general, molecules such as N_2, N_2O or CF_4 present much more excitation than rare gas atoms or molecules built with H atoms such as CH_4 or NH_3. Finally, the fragments electronic configurations show that multi-electron excitation is responsible for the molecular excited states.

Strong Field Molecular Optics

Misha Ivanov, David Villeneuve, Michael Spanner, Sergey Aseyev, and Paul Corkum

National Research Council of Canada, SIMS, 100 Sussex Dr., Ottawa Ontario K1A 0R6, Canada
phone (613)-993-9973, fax (613)-991-3437 , e-mail misha.ivanov@nrc.ca

Molecular optics shares with atom optics the aim of controlling position, velocity and acceleration. It also aims to control intrinsically molecular properties such as rotations, from alignment to angular acceleration.

Femtosecond technology opens two major avenues for controlling the dynamics of a quantum system such as a molecule. First, femtosecond pulses can be shaped into nearly arbitrary waveform, which can be adapted to achieving specific control objective. Second, femtosecond pulses can apply very strong forces to a quantum system (atom or molecule), modifying the quantum system and altering its dynamics.

I will describe how these two approaches are combined in strong-field molecular optics.

We use both high intensity and broad spectrum of femtosecond pulses to control alignment and angular acceleration of small molecules. Applying intense shaped laser pulses we:

- align small molecules,
- study how strong aligning field modifies the time scale of molecular response,
- spin small molecules in a controlled way to a desired rotational frequency in a given plane of rotations,
- force rotational dissociation.

Although molecules are much more difficult to cool than atoms, strong infrared fields allow us to create room-temperature deep traps (i.e. ~25 meV) for both translational and rotational motion, making cooling less critical. In our experiments we achieve 100 meV deep angular traps (corresponding to kT>1000 K) for diatomic molecules such as Cl2, with little ionization on 50ps time-scale.

On the other hand, strong non-resonant fields can also be used to enhance cooling of the translational motion of small molecules. The main principles of strong-field molecular refrigerator will be described in this talk.

Charge Resonance Enhanced Ionization Revisited – CREI – Role of Ionic States as Doorway States

A.D. Bandrauk[+], H.Z. Lu, Laboratoire de Chimie Theorique
Universite de Sherbrooke, Que, J1K 2R1, Canada;
I. Kawata, H. Kono, Graduate School of Science,
Tohoku University, Sendai 980-8578, Japan

[+] Tel.: 1-819-821-7098; FAX: 1-819-821-8017
e-mail: andre.bandrauk@courrier.usherb.ca

Abstract

The time-dependent Schroedinger is solved for the 3-D H_2^+ in an intense electromagnetic pulse and a static magnetic field. It is found that large magnetic fields suppress CREI thus supporting the one-electron quasistatic tunneling model for this effect. For comparison, a 1-D model for H_2 in an intense ($I > 10^{14}$ W/cm^2), short ($t \leq 50$ fs) laser pulse ($\lambda = 1064$ nm) is solved numerically to study two electron effects in CREI as discovered previously (A.D. Bandrauk *et al*, Phys. Rev. A54, 3290 (1996), A56, 685 (1997), A59, 539 (1999)). Adiabatic field induced electronic states and their time evolution show that CREI in two or even-electron systems differs from one lectron (e.g. H_2^+) or odd-electron systems by their excited charge transfer ionic states (e.g. H^+H^-) crossing the neutral covalent state (HH) at the critical distance R_c for enhanced ionization. An analytic expression is obtained for the crossing condition and hence for R_c in terms of three essential doorway states for two (even) electron systems. This is shown to agree with numerical results. Nonadiabatic field induced transitions are shown to determine R_c where near-crossing of the essential, doorway adiabatic states occurs. Rydberg-like (diffuse) electronic states dominate the ground state at the peak intensity in general at $R < R_c$ but do not contribute to the ionization dynamics. Similarly at $R > R_c$, the ionic state dominates the ground state but the dynamics evolve only on the neutral state. It is only at $R \simeq R_c$ that nonadiabatic field induced transitions are most important.

Molecular dynamics and control in ultrashort laser pulses

Eric Charron[1], Darian Stibbe[1] and A. Suzor-Weiner*[1,2]

[1] *Laboratoire de Photophysique Moléculaire, Université Paris-Sud, Bat. 210, F91405 Orsay*
[2] *Laboratoire de Chimie Physique, Université Paris 6, 11 rue P. et M. Curie, F75234 Paris*

*annick.suzor-weiner@ppm.u-psud.fr

Controlling the dynamics of atomic and molecular processes by means of laser radiation has received much recent attention, with the ultimate goal of controlling the outcome and branching ratios of chemical reactions. Experiments [1] and theory [2] are exploring various complementary approaches, based on the coherence properties of laser light, to analyze or manipulate the motion of electrons and nuclei. The temporal coherence is the most actively explored at the moment, due to the recent strides in the development of femtosecond technology.

Pump-probe experiments using sequences of ultrashort pulses to create and control electronic or nuclear wavepackets bring new insight into the timing of molecular processes [1]. Time-dependent simulations of such experiments will be reported, with emphasis on the control of competing ionization and dissociation processes [3]. Extension from isolated diatomic molecules (NaI) to small molecular clusters (NaI...CH_3CN, CsI... CH_3CN) will be discussed [4].

[1] R. J. Gordon and S. Rice, Ann. Phys. Chem. **48**, 601 (1997); S.A. Rice, Nature **403**, 496 (2000)

[2] J. Manz, in "Femtobiology and Femtochemistry", Ed. V. Sundström, World Scientif. Singap. (1998)

[3] E. Charron and A. Suzor-Weiner, J. Chem.Phys. **108**, 3922 (1997); G. Grégoire, M. Mons, I. Dimicoli, F. Piuzzi, E. Charron, C. Dedonder-Lardeux, C. Jouvet, S. Martrenchard, D. Solgadi, A. Suzor-Weiner, European Physical Journal **1**, 187 (1998)

[4] G. Grégoire et al., European physical Journal D, in press (2000); D. Stibbe, V. Brenner, E. Charron P. Millé and A. Suzor-Weiner, in preparation.

THE ROLE OF DISSIPATION IN MULTIELECTRON DISSOCIATIVE IONIZATION OF SMALL MOLECULES[†]

Mirosław Brewczyk
Uniwersytet w Białymstoku, ul. Lipowa 41,
15-424 Białystok, Poland
email: brewczyk@alpha.uwb.edu.pl

Kazimierz Rzążewski
Centrum Fizyki Teoretycznej PAN and College of Science,
Al. Lotników 32/46, 02-668 Warsaw, Poland
email: kazik@cft.edu.pl

Abstract

We investigate the interaction of many–electron systems with intense laser radiation in terms of the non–linear Schrödinger equation. The kinetic energy of the electrons is calculated based on the pure Thomas–Fermi approximation, however, the Weizsäcker correction is also considered. We introduce the dissipation into the system and find that it is necessary to get agreement with the experimental data on the multielectron dissociative ionization of small molecules. The interpretation of this necessary dissipation will be offered.

[†] supported by the MCS Grant No. PAN/NIST-98-340 and
Projet de Cooperation France-Pologne 177/R99.

Multicolor Detachment of a Negative Ion in the Presence of a Static Magnetic Field

S.Bivona, R.Burlon,C.Leone
Istituto Nazionale di Fisica della Materia and DEAF, Viale delle Scienze, 90128 Palermo Italy

The photodetachment of a negative ion by a weak uv electromagnetic field in the presence of a static magnetic field and a low-frequency (LF) bichromatic electromagnetic field, whose components have commensurate frequencies, is investigated.The case is treated in which the ejected electron may exchange a large number of photons of the LF field. It is found that when the relative phase of the LF field components is zero, the photoelectron flux along the magnetic field in the forward direction is different from the one in the backward direction.Moreover, the case is addressed in which the photodetachment is caused by the action of two weak uv fields whose frequencies differ by a small integer multiple of the frequency of a monochromatic LF assisting field, in the regime in which the cyclotron frequency is a multiple of the frequency of the LF field.

High Order Harmonic Generation of an Atom in the Presence of a Strong Laser Pulse

R. Daniele*, A. Di Piazza*, E. Fiordilino* and F. Morales#

* INFM and Dipartimento di Scienze Fisiche ed Astronomiche,
Via Archirafi 36, 90123 Palermo, Italy
Phone 39-091-6234238; Fax 39-091-6234281.
e-mail: daniele@fisica.unipa.it

INFM and Dipartimento di Fisica e Tecnologie Relative,
Viale delle Scienze, 90128 Palermo, Italy.
Phone 39-091-236320; Fax 39-091-236306.

We present calculations of the light spectrum emitted by an unidimensional atom in the presence of a laser pulse of the form

$$E(t)=E_0\left(\frac{t}{\tau}\right)^2\exp\left[1-\left(\frac{t}{\tau}\right)^2\right]sin(\omega_L t)$$

with τ ranging from 4 to 50 optical cycles.

The atom has been modelled by an electron moving in the presence of a soft core potential of the form

$$V(x)=\frac{-q^2}{\sqrt{a^2+x^2}}$$

with paramenters q^2 and a^2 chosen to mimic the energy gap between the two lowest bound levels of the hydrogen.

The spectra present a plateau of lines with a order depending blue shift.

Ab Initio Theory of Double Photoionization

P. Lambropoulos

Max Planck Institute for Quantum Optics, D-85748 Garching, Germany
and
Institute of Electronic Structure and Laser, FORTH, and Department
of Physics, University of Crete, Heraklion GR-71110, Crete, Greece

I discuss recent developments on the theory of double photoionization of Helium in the few-photon regime. The method is based on the expan-sion of the wavefunction in terms of eigenstates of the bare atom, expressed as linear combinations of B-splines. Techniques based on a radial box with a fixed boundary or alternatively a free boundary need to be and are employed. The results pertain to the photoelectron energy spectrum for two-photon double ionization, extending earlier work to a fully correlated calculation, within perturbation theory. In addition the non-perturbative solution of the time dependent Schrodinger equation is implemented in terms of the same method. Signatures of direct double ionization, especially for XUV photons are identified. Finally, ongoing work and results on the exploration of effects of laser coupling between triply excited hollow states of Lithium, based on similar techniques are briefly discussed.

THEORETICAL STUDY OF THE INTERACTION OF A TWO-ACTIVE ELECTRON SYSTEM WITH AN ULTRASHORT LASER PULSE

B. Piraux[1] and G. Lagmago Kamta[2]

(1) Laboratoire de Physique Atomique et Moléculaire,
Université Catholique de Louvain, 2, Chemin du Cyclotron
B-1348 Louvain-la-Neuve, Belgium

(2) Department of Physics and Astronomy,
The University of Nebraska, Lincoln, NE 68588-0111, USA

The behaviour of a two-active electron system exposed to a strong and ultrashort laser pulse remains a challenging theoretical problem which requires the non-perturbative solution of the three-dimensional time-dependent Schroedinger equation. The essential motivation is to understand the role of the electron-electron correlations in genuine two-electron processes like double excitation or (non-sequential) double ionization.

We will consider the interaction of He and H^- with a realistic laser pulse and analyse in detail the role played by the doubly excited states in the multiphoton ionization/detachment process. *Ab initio* calculations of the double excitation yield as well as the above-threshold ionisation/detachment spectra will be presented and discussed. These calculations are based on the numerical solution of the time-dependent Schroedinger equation by means of a spectral method. This method consists in expanding the total wave function of He or H^- on eigenstates which are built as products of Coulomb Sturmian functions of different non-linear parameters. The total wave function is then propagated in time by means of an explicit embedded Runge-Kutta formula. This way of expanding the total wave function on products of Sturmian functions of different non-linear parameters combined with a complex dilation of the Hamiltonian has revealed to be very efficient to generate accurately both the position and the width of a large number of doubly excited states.

Differential rates for nonsequential double ionization in intense laser fields

R. Kopold and W. Becker
Max-Born-Institut für nichtlineare Optik und Kurzzeitspektroskopie
Max-Born-Str. 2a, 12489 Berlin, Germany
ph.: +49-30-6392-1372, FAX: +49-30-6392-1309
email: wbecker@mbi-berlin.de

The analysis of multiple ionization in terms of sequential and nonsequential (where several electrons are ejected on a time scale comparable with or shorter than the laser period) processes sheds light on the role of the electron-electron interaction in atoms irradiated by intense fields. Recent experiments [1,2] have, for the first time, been able to measure *differential* rates rather than total ion yields. This additional information may lend support to some of the mechanisms of multiple nonsequential ionization that have been put forward and rule out others.

In this paper, we present quantum-mechanical calculations of the S matrix for nonsequential double ionization that are based on the presumed dominance of the classical action for the evolution of the process. The method is an extension of, e.g., the Lewenstein model for high-harmonic generation. Consistent use is made of the strong-field approximation, that is, the action is approximated differently at different stages of the process: the effect of the laser on bound states is neglected as well as the action of the binding potential on continuum states except at the instant of rescattering. All charged-particle interactions including the vital electron-electron interaction are approximated by contact interactions. We consider double ionization effected by inelastic rescattering according to two different scenarios: the returning first electron either directly kicks out the second electron or it lifts it into an excited state from where it tunnels out at a later time. The first scenario yields distributions for the total electronic momentum in good agreement with the data in neon [2] while the latter produces distributions not unlike those measured in helium [1].

This work was partially supported by Deutsche Forschungsgemeinschaft.

[1] Th. Weber et al., Phys. Rev. Lett. **84**, 443 (2000).
[2] R. Moshammer et al., Phys. Rev. Lett. **84**, 447 (2000).

Role of Correlation and Final-state Volkov Dressing on the Dynamics of Laser Induced Double Ionization".

F.H.M. Faisal and A. Becker

Fakultaet fuer Physik, Universitaet Bielefeld, D-33615 Bielefeld, Germany.

Until recently the single active electron (SAE) ansatz of intense field laser-atom interaction had proved to be very adequate in understanding the non-pertuibative dynanu'cs of laser-atom interaction, hke above-threshold ionisation (ATI), higher orderharmonic genctation (HHG), or adiabatic stabilisation (AS). The first major departure from this rule has been revealed by observations of large non-sequential (NS) contributions to the total yields of double (and multiple) ionisation of noble gas atoins in feintosecond laser pulses, e.g. [1-3].

It has since been understood (e.g., [4,5] and refs. [1-27] cited in [5b]) that the NS mechanism is impossible without a strong mediation of electron-electron correlation, and hence it lies outside the scope of the SAE ansatz. In the past we have shown [4,5] that a systematic approximation method for the analysis of double and multiple ionisation, including the NS contribution, is provided by the so-called 'correlated energy-sharing diagram', in which one electron absorbs a large amount of energy froin the field and shares it with the other electron via electron-electron correlation (that involves both 'scattering' and 'rescattering' events in an 'internal e-2e' process) until both the electrons niight have enough energy to escape together froin the binding force of the nucleus. This mechanism is arrived at by analysis of the leading order processes for laser induced double (or multiple) ionisation using the so-called intense-field many-body S-matrix theory (IMTS) [4]. The predictions of this theory has provided so far the best agreements between all the available theories and the experimental data for both double and multiple ionisations in intense laser fields.

A remarkable new development in this context is the recent measurments [6,7] of the distributions of the recoil momentum of the doubly charged ion, both parallel and perpendicular to the polarisation axis of the laser. The recoil momentum is directly related to the sum of the moments of the two outgoing electrons. Hence these differential distributions of the moments of the two electrons not only go beyond those of the total yields of doubly charged ions, but also provide a more stringent test of any model of double ionisation in intense laser fields. It has been pointed out in [7], for example, that that the so-called shake-off model [31 and the 'collective tunneling' model [8] are not consistent with their observed data.

The first consistent theoretical analysis of the distributions of the recoil momentum of doubly charged ions of He have been given recently [9]. This reproduced all the salient features of the observed distributions both in the parallel and in the perpendicular directions. Quantitative analysis in the case of double ionisation of He at the highest intensity measured (6.6 E(+14) W/cm^2, [6]) dernonstrated that:

(a) the characteristic double-hump structure of the distribution of the parallel component of the recoil momentum is both a consequence of electron-correlation and the final-state laser interaction with the two out-going electrons (a final-state 'Volkov dressing' effect);
(b) the maximum widths of the observed wide distributions in the parallel direction are shown to follow a cut-off maximum of the sum of the two electron moments, given by the simple fonnula.P(cut-of)=Re{4sqrt(Up)+sqrt(8Up - E(B)}, where Up is the poderomotive energy, and E(B) is the binding energy of the electrons;
(c) (c) the distribution for the perpendicular cotnponent of the recoil momentum is predicted to be rnuch narrower than those for the parallel comportent; this is consistent with the data and is found to be a consequence of the effective de-coupling of the final-state Volkov dressing, in the direction perpendicular to the polarisation axis.

The above and the related conclusions will be discussed using the results of concrete theoretical calculations and comparisons with experimental data.

References:

1. D.N. Fittinghoff et al., Phys. Rev. Lett. 84, 447 (1992).
2. B. Walker et al., Phys. Rev. Lett., 73, 2642 (1994).
3. A. Taiebpour et al., J.Phys. B, 30, 1721 (1997).
4. F.H.M. Faisal and.A. Becker, (a) Conunents on Mod. Phys. D 1, 15 (1999); (b) in Selected Topics on Electron Physics, eds., D.M. Campbell and H. Kleinpoppen (N.Y..- plenum, 1996) p.317.

Correlation in strong field atomic double ionization: The momentum distribution of the photoelectrons

H. Rottke, C. Trump, M. Wittmann, G. Korn, W. Sandner
Max-Born-Insitut, Max-Born-Str. 2a, D-12489 Berlin, Germany,
Tel.: +49 30 6392 1370, e-mail: rottke@mbi-berlin.de
R. Moshammer, A. Dorn, B. Feuerstein, C. D. Schröter, D. Fischer, W. Schmitt,
J. Crespo, J. Ullrich
Dep. of Physics, University of Freiburg, Herrmann-Herder-Str. 3,
D-79104 Freiburg, Germany
P. Neumeier
GSI Darmstadt, Planckstr. 1, D-64291 Darmstadt, Germany

Identifying the mechanism governing non-sequential atomic double ionization in strong laser fields has been the goal of many experimental investigations in recent years. Up to now these investigations have not been able to identify the mechanism unambiguously. Several mechanisms such as for example shake, rescattering, and collective electric field ionization have been proposed.

We are investigating the distribution of the momenta of the photoion and photoelectrons emerging from atomic strong field double ionization. It can be shown that for multiple ionization in the non-relativistic regime the momentum of the photoion is, to a good approximation, equal and directed opposite to the sum-momentum of the photoelectrons. This helps a lot to get kinematically complete information on the ionization process. We measured the momentum vectors of the charged particles using the well established COLTRIM (COLd Target Recoil Ion Momentum) Spectroscopy.

The momentum distributions of Ne^{n+} (n = 2, 3) and Ar^{2+} photoions show a pronounced characteristic doubly peaked structure along the polarization direction of the light wave if the light intensity is chosen in the non-sequential regime for double and triple ionization. In case of Ne the well separated maxima appear at $p_{||} = \pm 4$ *a.u.* and $p_{||} = \pm 7.5$ *a.u.* for Ne^{2+} and Ne^{3+}, respectively, at a light intensity of $\approx 1.3 \times 10^{15}$ W/cm^2. The separation of the maxima changes in proportion to the square root of the ponderomotive potential of an electron in the light wave. The double peak structure collapses into a single narrow maximum located at zero momentum when the light intensity is increased into the regime where double ionization becomes sequential. The distribution of the ion and therefore of the electron sum momentum in this regime looks similar to that for single ionization of the atoms. The double maximum structure in the electron sum momentum distribution immediately rules out all non-sequential multiple ionization mechanisms which put the electrons into the ionization continuum simultaneously at field strength maxima of the oscillating electric field of the light wave. The experimental results strongly point to inelastic rescattering as the main mechanism for non-sequential double ionization.

Details concerning the non-sequential ionization mechanism are found in the distribution of the difference momentum of the two photoelectrons ($\vec{p}_{e1} - \vec{p}_{e2}$). The measured distribution function for $p_{e1,||} - p_{e2,||}$ shows a sharp minimum at $p_{e1,||} - p_{e2,||} = 0$ if one restricts the momentum of one of the photoelectrons to small values perpendicular to the polarization direction of the light. This minimum is filled up if only large transverse momenta are taken into account. This behaviour seems to point to a final state interaction of the two photoelectrons via mutual Coulomb repulsion. Summarizing, the electron momentum distributions show a strong e-e correlation in the non-sequential regime of strong field double ionization.

MULTI-ELECTRON IONIZATION DYNAMICS IN STRONG LASER FIELDS

Wolfgang Sandner
Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy
Max-Born_Str 2a 12489 Berlin, Germany
Tel.: +49-30-6392-1300, Fax.: +49-30-6392-1309
e-mail: sandner@Pmhi-herJin.de

It is well understood that nonsequential multiple ionization in strong laser fields is based on electron-electron correlations, even if the exact mechanism is under vivid discussion. Some recent progress will be reviewed in this talk.

First, we have completed our studies on the novel mechanism of collective simultaneous tunneling, proposed for the first time at LPHYS'98. We found that collective tunneling ionization (CII) is, in principle, a valid mechanism for nonsequential multi-electron ionization. It occurs through a highly correlated "tunneling motion" of the electrons: they must maintain equal radial distance from the core, or the lagging electron gets immediately captured [1]. The calculated CTI rates turn out are far too small to reproduce the data in strong laser fields. We found, however, that this process may be dominant under certain circumstances, such as ionization in half-cycle pulses, where the competing re-scattering mechanism is absent and the sequential process is strongly suppressed due to the short time duration of the pulse.

Our efforts to connect the CII mechanism with a simple phenomenological formula, also proposed earlier from our laboratory, failed [1]. This appears to be an interesting open problem since the formula a) has the mathematical structure of a modified CTI formula or, alternatively, a modified one-electron ADK tunneling formula, and b) is able to reproduce almost ail available data for the total yields of multiply charged ions in linearly polarized fields. Strictly speaking, it seems to be possible to take the ADK-formula, modify it in a simple, but unambiguous way and get a fair, parameter-free description of multi-electron ionization processes which are, from ail we know, not governed by tunneling but by rescattering.

In order to finally settle the question about the underlying mechanism, two German collaborations (Frankfurt/Giessen and Freiburg/MBI Berlin) have, for the first time, measured the momentum distribution of the doubly or multiply charged ions which is equivalent to the distribution of the total electronic momentum. The data provide strong support for the rescattering mechanism [2,3]. This has been shown by a new theoretical model from our laboratory [4], following the lines of the Landau-Dykhne-Keldysh approach and the strong-field approximation and calculating the quantum-mechanical probability amplitude via an approximation to Feynman's path integral. On the assumption of a rescattering scenario, the distribution of the total electronic momentum is obtained in good agreement with the data in neon. For helium at low intensities there seem to be some discrepancies, which may qualitatively be explained by the occurrence of excited states in the rescattering picture. Results have also been obtained for other rare gases and various intensities. Experimentally, the data have meanwhile been completed by the measurement of electron-ion correlations, which are presently being analysed and will be presented.

This work was partially supported by Deutsche Forschungsgemeinschaft DFG.

References:

[1] U. Eichmann et ai, Phys. Rev. Lett. 84, (2000), in print
[2] R. Mooshammer et ai., Phys. Rev. Lett. 84, (2000), 447;
[3] lb. Weber et ai, Phys. Rev. Lett. 84, (2000), 443
[4] R. Kopoid et ai., submitted to Phys. Rev. Lett

9th Annual International Laser Physics Workshop (LPHYS'2000), July 17-21 2000, Bordeaux, France
Seminar on Strong Field Phenomena

Resonant and non-resonant ionization of helium by XUV ultrashort and intense laser pulses

H. Bachau, E. Cormier, R. Hasbani
Centre Lasers Intenses et Applications, Université de Bordeaux I,
351, Cours de la Libération
33405 Talence, France
e-mail : bachau@celia.u-bordeaux.fr
fax : (33) 5 57 96 25 80

Abstract.

We study the multiphoton ionization of He by a strong ultrashort laser pulse. The time dependent Schrödinger equation (TDSE) is solved by means of a spectral method of configuration interaction type (CI). Our method is based on an expansion on B-spline products for the (two-dimensional) radial part, and dipolar spherical harmonics for the (four-dimensional) angular part. Our approach permits to treat properly electron correlations so as to provide an accurate description of many eigenstates simultaneously. We will study the multiphoton ionization of helium with photon energies ranging from 5.4 eV to 34 eV. Emphasis will be put on the excitation of autoionizing states of helium by laser pulses whose the duration is shorter than the autoionization lifetime. The wavefunction is analysed at the end of the pulse in position and momentum spaces, and double electron excitation and/or ejection is discussed for various photon energies.

OPTIMIZATION OF CALCIUM ATOM DOUBLE IONIZATION WITH PHASE-SHAPED FEMTOSECOND LASER PULSES

(invited talk)

M. Strehle, G. Gerber
Physikalisches Institut, Universität Würzburg, D-97074 Würzburg, Germany
gerber@physik.uni-wuerzburg.de

Time-resolved experiments in atomic calcium were performed by combining fs-laser technology with electron and ion time-of-flight spectroscopy. By controlling the laser intensities we studied effects in the weak field limit (Rydberg wave packet dynamics) as well as in strong laser fields (time-resolved multiphoton ionization). In the case of moderate laser intensities we observed the temporal evolution of an electronic radial Rydberg wave packet by employing the phase sensitive technique on the detection of photoelectrons (1).

With higher intensities for both the ultraviolet pump laser and the infrared probe laser we observe by multiphoton ionization (MPI) singly and doubly ionized calcium atoms. In pump-probe experiments we measured the temporal dynamics of the formed ions. When both laser pulses temporally overlap we observe a significant variation of the Ca^{+}- and Ca^{++}-yields, which we believe is due to the lifetime of autoionizing states (AIS) which can be reached with our pump laser pulses as intermediate states (2).

When we employ tailored femtosecond laser pulses from a computer-controlled feedback-optimized pulse shaper (3) to control the yield of singly or doubly ionized calcium atoms we found a strong chirp dependence of the multiphoton ionization processes. The obtained optimized fields find may be used to understand the ionization pathways.

(1) M. Strehle, U. Weichmann, and G. Gerber, Phys. Rev. A 58, 450 (1998)
M. Strehle, C. Völker, U. Weichmann, and G. Gerber
Ultrafast Phenomena XI, eds. T. Elsaesser, J.G. Fujimoto, D.A. Wiersma, W. Zinth
Springer Series in Chemical Physics, Vol. 63, 435 (1998)
(2) P. Lambropoulos and P. Zoller, Phys. Rev. A 24, 379 (1981)
(3) T. Baumert, T. Brixner, V. Seyfried, M. Strehle, and G. Gerber Appl. Phys. B65, 779(1997)

Telephone: ++49 931 888 5715
Fax: ++49 931 888 4906
E-mail: gerber@physik.uni-wuerzburg.de

RELATIVISTIC EFFECTS IN LASER-ATOM INTERACTIONS

C.J. Joachain

Physique Théorique, Université Libre de Bruxelles, Belgium

Relativistic effects arise when atoms interact with ultrastrong laser fields. Such effects are expected to become important when the ratio of the ponderomotive energy U_p of an electron in the field to the electron rest mass energy becomes comparable to unity. In atomic units, this ratio is $q = U_p/c^2 = \mathcal{E}_0^2/(4\omega^2 c^2)$, where $\mathcal{E}_0$ is the peak strength of the electric field, ω is the angular frequency of the laser light and c is the velocity of light. Recent progress in the theoretical study of several relativistic effects in laser-atom interactions will be discussed: influence of the magnetic component of the laser field, relativistic mass shift due to the dressing of the electron mass by the laser field, negative energy states and spin effects. Particular attention will be paid to the modifications of the laser-atom dynamics in the high-intensity, high-frequency regime where non-relativistic theories predict a decrease of the ionization probability of atoms with increasing laser intensity.

Abstract for the Strong Fields Seminar
for the LPHYS conference Bordeaux July 17-21 2000

Title: Relativistic Ionization Dynamics in a 1D Model

Authors: Ernst Lenz, Martin Doerr, and Wolfgang Sandner
e-mail: doerr@mbi-berlin.de
http://mitarbeiter.mbi-berlin.de/doerr

Affiliation: Max Born Institut, D-12489 Berlin, Germany

We consider the time dependence of a strongly
bound electron in one dimension under the influence of a short,
relativistically strong, ionizing field pulse.
Results are compared from the numerical solution of the
nonrelativistic Schroedinger equation (N), its
relativistic variant (R), and the 1D Dirac equation (D).
Kinematic effects due to the relativistic speed of the
wavepacket are well described by (R), in agreement with (D),
and contrasted to (N).
The (D) solution exhibits extra structure, due to the small
component.

Ionization dynamics at relativistic laser intensities

U. Eichmann, M. Dammasch, M. Kalashnikov and W. Sandner
Max Born Institut, Max Born Str. 2a, D 12489 Berlin, Germany
Phone: 49 30 63921371
Fax: 49 30 6392 1309
eichmann@mbi-berlin.de

We have recently started a program to investigate atomic ionization processes at relativistic laser intensities using the high intensity Ti-Sapphire laser at the Max Born Institute. Understanding of the ionization processes at these high intensities is not only of fundamental interest, but might have further implications for other areas in physics, such as theoretical modeling of laser produced plasma.

For fs-laser pulses and laser intensities below 10^{16} W/cm^2 nonsequential ionization processes are known to strongly influence the ionization dynamics. Especially below the saturation intensity with respect to a certain charge state simultaneous ionization processes enhance the multiply charged ion yield by orders of magnitude, while above saturation the sequential picture, best described by the ADK tunneling model, prevails. Available experimental ion yield data can be well understood with a rescattering picture [1], which also explains measured momentum distributions of multiply charged ions created by strong laser fields[2].

Up to now ion yield measurements for laser intensities above 10^{16}W/cm^2 are scarce. Here, we report the first measurements on multiple ionization of Xe up to Xe^{21+} corresponding to weakly relativistic laser intensities of $I > 10^{18}$W/cm^2 .We compare our data with the results of rate equations using ADK rates for the sequential process and an empirical formula for the nonsequential rates, which has been proven to cover nonsequential effects with an astonishing accuracy [3]. The results suggest that the empirical formula is also valid in the high intensity regime. This poses the interesting question of the relevance of the rescattering process, which is expected to be of minor importance at relativistic intensities.

1) P.B. Corkum, Phys. Rev. Lett **71**, 1994 (1993).
2) R. Moshammer et al., Rev. Lett **84**, 447 (2000); Th. Weber et al., Rev. Lett **84**, 443 (2000).
3) U. Eichmann et al.,Phys. Rev. Lett. **84**, April (2000).

9th Annual International Laser Physics Workshop (LPHYS'2000), July 17-21 2000, Bordeaux, France
Seminar on Strong Field Phenomena

Ionisation of hydrogen and alkaline atoms by intense femtosecond and sub-femtosecond laser pulses

G. Duchateau, E. Cormier and R. Gayet
Centre Lasers Intenses et Applications, Université de Bordeaux I,
351, Cours de la Libération
33405 Talence, France
e-mail : gayet@celia.u-bordeaux.fr
fax : (33) 5 57 96 25 80

Abstract.

In the last few years, femtosecond *terawatt* lasers have been developed and intensities as high as 10^{18} $W.cm^{-2}$, or even higher, have been achieved. When atoms of gas or small clusters are illuminated by so short and intense laser pulses, a highly ionized plasma is created in a time much shorter than the pulse length. Under such conditions, total ionization is completed within a few atomic units of time (actually, it is completed after the first half cycle of a 10^{18} $W.cm^{-2}$, *20 fs*, *800 nm* laser pulse). Therefore, it appears interesting to study the ionization of an atom during the early rise of an ultra-intense laser pulse. At CELIA, a non-perturbative theoretical approach, based on bound Coulomb-Volkov-type (CV) states, has been introduced to predict the evolution of both angular and energy distributions of the ejected electrons. CV predictions are compared to results obtained with a full numerical treatment of the Schrödinger equation, based on B-spline basis set expansions. For atomic hydrogen and alkaline atom targets, we found that the present theory makes accurate predictions as long as the interaction time does not exceed one or two optical cycles (multigigawatt laser pulses with less than two optical cycles have already been generated at $\lambda = 800nm$ in Wien by M. Nisoli *et al.*, Opt. Lett. **22**, 522 (1997)). In addition it is shown that good predictions may be issued as long as the interaction time does not exceed half of the initial orbital period of the electron. Predictions are all the better as the laser field amplitude is high and the initial quantum number is large.

Numerical solution of Dirac equation and its applications in intense laser physics

Q. Su and R. Grobe

Intense Laser Physics Theory Unit
and Department of Physics
Illinois State University
Normal, IL 61790-4560

309-438-5392 (phone)
309-438-5413 (fax)
qcsu@ilstu.edu

The time-dependent Dirac equation is solved numerically [1] to study electron dynamics in the presence of Coulomb, external laser and static magnetic fields. This approach is applied to investigate quantum relativistic effects. Recently a new electronic state referred to as cycloatom has been be realized. [2] We propose a mechanism for experimental investigation [3] of relativistic effects in the laser-atom interaction with moderate (non-relativistic) laser intensities that involves placing the system in a static magnetic field parallel to the laser's magnetic field component. The resonantly induced relativistic motion of the atomic electron leads to a variety of novel phenomena: a relativistic dephasing leading to a ring-like spatial probability density, a counter-intuitive window of relativistically enhanced motion, and a sequence of saw-tooth shaped resonances that may increase the harmonic generation. We compare the time evolution of the quantum mechanical spatial probability density obtained by solving the time-dependent Dirac equation with its classical counterpart obtained from the relativistic Liouville equation for the phase space density in a regime in which the dynamics are essentially relativistic. For a resonantly-driven one-dimensional harmonic oscillator, the simplest non-trivial model system to perform this comparison, we find that, despite the nonlinearity induced by relativity, the classical ensemble description matches the quantum evolution remarkably well. [4] The same approach to the relativistic tunneling process and a new concept of an instantaneous superluminal velocity under the potential barrier will be discussed as well.

* Supported by grants from the NSF PHY-9970490, Research Corporation PHY-CC4089 and Illinois State's URG.

[1] J.W. Braun, Q. Su and R. Grobe, Phys. Rev. A 59, 604 (1999).
[2] R.E. Wagner, Q. Su and R. Grobe, Phys. Rev. Lett. (accepted).
[3] R.E. Wagner, Q. Su, and R. Grobe, Phys. Rev. A 60, 3233, 1999.
[4] R.E. Wagner, P.J. Peverly, Q. Su and R. Grobe, Phys. Rev. A (accepted).

Strong Field Physics in a Scaled Interaction

Louis F. DiMauro and B. Sheehy
Brookhaven National Laboratory

Over the last decade, the tailoring of a light field for manipulating the dynamics of a system at the quantum level has taken a prevalent role in modern atomic, molecular and optical physics. As first described by Keldysh, the ionization of an atom with an intense laser field will scale depending upon frequency and binding energy. In this talk, we will discuss the physics of an alkali metal atom interacting with an intense mid-infrared laser field. Both ionization and harmonic processes are investigated. This understanding provides a roadmap for a quantum jump in ultra-short pulse technology. New experiments will be presented which illustrate the appropriateness of strong-field scaling laws and the physics associated with the formation of light pulses on the atomic time-scale (attosecond).

Helicity dependent angular distributions in two color ionization of hydrogen-like atoms

Magda FIFIRIG(*) and Aurelia CIONGA(**)

(*) Department of Chemistry, University of Bucharest, ROMANIA
(**) Institute for Space Sciences, Bucharest, ROMANIA

The effect of the helicity of the photons on the angular distributions (AD) of ejected electrons in multiphoton ionization of atoms was investigated theoretically for elliptic polarization. We discuss here the case of a bichromatic field that has two components of commensurate frequencies. One component is circularly polarized (CP), the other one is linearly polarized (LP) and the geometry corresponds to an experimental set-up. First, we notice that the calculated azimuthal AD are asymmetric; then we see that AD are sensitive to the change of the helicity of the CP photons. We shall present theoretical results concerning the domain of field parameters (frequencies, intensities) in which our calculations show that the effect of circular dichroism is important.

The Wigner function for tunneling in a uniform static electric field

A. Czirják a), R. Kopold b), W.Becker b), M. Kleber c), W.P. Schleich a)
a) Abteilung Quantenphysik, Universität Ulm, 89069 Ulm, Germany
b) Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany
c) Physik-Department T30, Technische Universität München, 85747 Garching, Germany

The Wigner function is used to study a simple model system for strong-field induced ionization: an electron tunneling out of a zero-range potential in the presence of a uniform static electric field.
We derive an analytic axpression for an approximate Wigner function describing a stationary situation where the part lost to ionization is continuously replenished. This approach is well justified by comparison with the true time dependent Wigner function obtained by numerically solving the one-dimensional problem. The three- and one-dimensional Wigner funktions both suggest that the electron leaves the tunnel with a non-zero velocity.
(C)2000 Elsevier Science B.V. All rights reserved.

The generalized Keldysh model in the tunneling regime.

S.P.Goreslavskii
Moscow State Engineering Physics Institute, 31 Kashirskoe shosse, Moscow, 115409, Russia
e-mail:grslv@theor.mephi.msk.su

The talk presents quantum amplitudes of Keldysh- type models for high harmonic generation [1,2], elastic rescattering [3,4] and double ionization [5,6] simplified. owing to a small value of the adiabaticity parameter γ. Multiple integrals are approximately calculated by a saddle – point method [7,8].

It is shown that the electron and/or harmonic distributions derived by saddle – point method in its standard form (assuming isolated stationary points) could be transformed by a change of variables to the form adopted by the corresponding „simple man" theory. Quantum results contain interference terms in addition to the „simple man" contribution. Classical kinematics comes into play through equations for the stationary points.

An important point is that the standard saddle – point procedure and, hence, the „simple man" approaches are not applicable for calculations of the distributions near the cutoffs imposed by the classical kinematics. A modified version of the saddle – point method is used to derive these parts of the distributions [8]. Such boundary distributions match the results obtained by the standard procedure inside the classically permitted domain and gradually decay outside it. In the case of rescattering it describes vicinity of the last interference maximum on the high energy ATI plateau at a fixed emission angle and the angular distribution of rescattered electrons around the largest maximum at the cutoff angle [8].

The 6d distribution in the total and relative momenta of the two emitted electrons is found in the case of double ionization. It contains the differential cross section of $(e,2e)$ inelastic collision in the Born approximation. The distribution in the total momentum along the field has been calculated by integration over the relative momentum. The result is in a good agreement with recent experimental measurements of the ion recoil momentum distribution [9] in regard of shape and position of the maximum. The latter is sensitive to changes in shape of the impact ionization cross section. That supplements the conclusion in [9] that at intensities of order $10^{15} W/sm^2$ just the returning to the ion electrons are responsible for production Ne^{2+} ions.

This work was partially supported by the Russian Foundation for Basic Research (projects 99-02-17810 and 00-02-17078)

References.

1. Lewenstain M et al, Phys Rev A 49, 2117 (1994)
2. Becker W et al Phys Rev A 50, 1540 (1994)
3. Lewenstain M. et al , Phys Rev A 51, 1495. (1995)
4. Lohr A. et al. Phys. Rev. A 55, R4003. (1997)
5. Kuchiev M, J. Phys. B: At. Mol. Opt. Phys. 28, 5093 (1995)
6. Faisal F H M, Becker A, NATO ASI Series, Ser. 3:, 13, 317 (1996)
7. Goreslavskii S P, Popruzhenko S V, Phys. Lett. A .249, .477.(1998)
8. Goreslavskii S P, Popruzhenko S V, J. Phys. B: At. Mol. Opt. Phys. 32, L533. (1999)
9. Rottke H et al, Abstracts ICOMP-8, LV (1999)

Accurate calculations for laser-driven helium in full-dimensionality

K.T. Taylor, J.S. Parker, L. R. Moore and D. Dundas

School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, U.K.

Rapid developments in high-intensity laser technology over the past decade has provided experimentalists with a source of polarized monochromatic electromagnetic radiation with which to violently agitate even the innermost electrons of an atom or molecule. The violent interaction takes place over such a short time scale ($\sim$ 20 fsec) that the wavefunction for the atomic electrons

evolves quickly and has no opportunity to be dominated by any stationary character. Thus the theorist is presented with an opportunity to study atomic electron dynamics far from equilibrium. Electron-electron interaction plays a role that is very different from that it plays in stationary atomic processes (electron-atom scattering, for instance) since now there is no longer infinite time for interactions to be equilibriated.

Helium, with just two electrons, is the simplest atom where electron-electron interaction comes into play. Some time ago we embarked on a theoretical/computational study of the response of this atom to a high-intensity, linearly-polarized laser pulse. With such a pulse, the electronic motion has just 5 degrees of freedom -the overall component of angular momentum along the polarization direction is still conserved. The foundation of our study has been to integrate directly the time-dependent Schrödinger equation for a wavefunction solution that spans all five spatial dimensions i.e. both electrons of the atom are treated on an equal footing. The code we have developed handles the three angular variables by a basis-set expansion over partial-waves and the radial variables are represented over a finite-difference mesh. Our calculations are now quantitatively accurate and, for example, reproduce field-free helium energies to within 0.02%. The primary applications of the full-dimensional integration have been to (a) provide support for the design of simplified (reduced-dimensionality) models by rigorously establishing their ranges of validity (if any) [1], (b) enable calculations of intense field (2-electron) phenomena that no reduced-dimensionality or ad-hoc theory can reliably or accurately model [2] and (c) provide a stepping stone for a full-dimensionality treatment of the 3-body [3] and 4-body problems presented by laser-driven H_2^+ and H_2.

We have work in progress addressing a number of facets of laser-driven helium. Some of those that will be reported on at the meeting include:

- the response of the atom to short wavelength ($\sim$20 nm), high intensity (10^{16} W/cm^2) laser radiation
- the investigation of the time-evolving wavefunction in momentum space
- comparison with laboratory experiment findings at 390 nm

[1] 'One- and two-electron numerical models of multiphoton ionization of helium' Parker J S, Moore L R, Smyth E S and K T Taylor 2000 *J Phys B: At Mol Opt Phys* **33** 1057; 'Time-dependent and time-independent methods applied to multiphoton ionization of helium' Parker J S, Glass D H, Moore L R, Smyth E S, Taylor K T and Burke P G 2000 *J Phys B: At Mol Opt Phys* **33** L239

[2] 'Double ionization dynamics of laser-driven helium' Dundas D, Taylor K T, Parker J S and Smyth E 1999 *J Phys B: At Mol Opt Phys* **32** L231; 'Laser-driven helium in full-dimensionality' Taylor K T, Parker J S, Dundas D, Smyth E and Vivirito S 1999 Laser Physics **9** 98

[3] 'Ionization dynamics of laser-driven H_2^+' Dundas D, McCann J F, Parker J S and Taylor K T submitted to *J Phys B: At Mol Opt Phys*

Optical breakdown in dielectric solids

F. Quéré, S. Guizard and Ph. Martin

Ecole Polytechnique

Laboratoire des Solides Irradiés

CEA-DSM-DRECAM/ CNRS (UMR 7642)

91128 PALAISEAU Cedex France

quere@drecam.cea.fr

What are the conduction electrons injection mechanisms involved in laser-induced breakdown of dielectric solids ? This question has been the object of numerous research almost since the invention of lasers, and has been recently revived in the case where pico or femtosecond pulses are used to destroy the solid. For this duration range, it has been recently proposed that most of the conduction electrons are injected through an electronic avalanche, which would be initiated by a weak density of free carriers initially excited by multiphoton absorption. So far, the experimental evidences for this scenario are very indirect : it mainly consists in measurements of the breakdown threshold as a function of pulse duration. The aim of our experiment was to make a direct observation of this avalanche process.

We have used time-resolved interferometry in the frequency domain to measure the instantaneous change of refractive index of a dielectric induced by an intense laser pulse. We will demonstrate how this measurement can give access to the total conduction electron density excited by the laser pulse. Thus, we have been able to measure this excitation density as a function of various parameters, such as the pump intensity and duration, both below and above breakdown threshold. All these measurements can be interpreted with multiphoton excitation of valence electrons as the only injection mechanism, both above and below breakdown threshold, which is in contradiction with the models based on a strong electronic avalanche. We will suggest why measurements of the breakdown threshold as a function of pulse duration can lead to erroneous conclusion concerning the injection mechanism.

B.C. Stuart et al, Phys. Rev. B 53, n°4, p. 1749 (1996)

The effect of laser-induced oscillating double layers on nonlinear photoemission at metal surfaces

Sándor Varró
Research Institute for Solid State Physics and Optics
Hungarian Academy of Sciences
H - 1525 Budapest, P.O.Box 49, Hungary
phone : ++ (36-1) 3 959 220 , fax : ++ (36-1) 3 959 286
e - mail : varro@sunserv.kfki.hu

The concept of the laser-induced oscillating double layer potential introduced in an earlier study (S. Varró, F. Ehlotzky : High-order multiphoton ionization at metal surfaces by laser fields of moderate power. *Phys. Rev.* **A57**, 663-666 (1998)) has been originally worked out to explain a surprising outcome of an earlier experiment by Farkas and coworkers, namely, the appearance of very large (~600 eV) energy photoelectrons induced by Nd:Glass laser radiation ($h\nu \sim 1.17$ eV) at moderate intensities of some 10 GW / cm^2. The main problem was that the very large nominal order of the photon absorption processes corresponding to the experimental results (n ~ 5-600) could not have been deduced from the usual non-perturbative approach based on Gordon-Volkov states, since the intensity parameter μ was of order of 10^{-4} in that case. That time we have realized that instead of μ , another basic dimensionless parameter „a" appears in the analysis in a natural way, when we introduce the interaction with the double layer potential which builds up due to the coherent collective excitation of all the electrons within the skin depth. The parameter „a" is defined as $a = 2V_1 / \hbar\omega$, where $V_1 = (\omega_p / 2\omega) \mu mc^2$ is the amplitude of the double layer potential being proportional to the plasma frequency ω_p . The size of this „a" governing the degree of nonlinearity turned out to be just of order of 500 for the mentioned experiment, hence we were able to explain the the basic features of the measured electron spectra.

In the present work we have applied the above mentioned model for a different situation in order to see whether we can interpret the recent experimental results (Gy. Farkas et al : Infrared electron photoemission from a gold surface. *J. Phys. B: At. Mol.Opt.Phys.* **B31**, L461-L468 (1998)) concerning electron emission from gold cathodes (work function ~5 eV) irradiated by mid-infrared radiation (generated by the Orsay FEL) of wavelength up to 12 μm ($h\nu \sim 0.1$ eV) in the I ~ 10 MW / cm^2 intensity regime. As was pointed out by the authors of this paper, both the tunneling model and the multiphoton model predict numbers many (more than hundred) orders off the experimental figures. For an explanation they introduced the concept of „lucky electrons" , based on a classical acceleration mechanism. We give an alternative quantummechanical description based on our dipol layer model. Since in the present case the mean collision frequency of the electrons is comparable with the frequency of the radiation, the electrons in the bulk do not contibute to the collective coherent excitation of the double layer potential. Only evanescent electrons in a thin layer above the surface make a contribution. By using the Floquet method we have found an approximate analytic solution of the quantummechanical barrier problem of the electrons scattered by the oscillating double layer potential at the surface of the metal. We have found that the photoelecton spectra are governed by the formula $j_n \sim I_n(a^2 / 2) \exp(- a^2 / 2)$, where I_n denotes the n-th order modified Bessel function of first kind, and the parameter „a" is now of order ~ 30. The theoretical results based on this formula reflect excellently back all the characteristics of the observed photoelectrons, namely the unexpectedly wide above threshold spectrum extending up to 2 eV (corresponding to ~ 70 photon absorption), the intensity dependence $d \log j / d \log I \sim 6$ and the very high total photocurrent $j \sim 1$ mA / cm^2 .

The present work has been supported by the National Science Foundation of Hungary under contract number OTKA T032375.

COMPUTER EXPERIMENTS ON ATOMIC STABILIZATION IN A STRONG LASER FIELD

Popov A.M., Tikhonova O.V., Volkova E.A.

Institute of Nuclear Physics, Moscow State University, 119899, Moscow, Russia,
tel.: 7-095-9394954, fax: 7-095-9394956, e-mail: popov@mics.msu.su

The investigation of the ionization dynamics of 3D hydrogen-like atom was performed in a wide range of laser pulse parameters and for different initial atomic states $|nlm\rangle$ by the method of the direct numerical integration of the non-stationary Schroedinger equation.

The structure of the energy spectrum of the atom in the presence of the electromagnetic field was analyzed. It was found that in the case of one-photon ionization the atomic potential in the presence of the laser field is modified to the KH potential and the atom exists in the form of the KH atom. In the low intensity limit (the amplitude of the free electron oscillations is less then typical atomic size $\alpha_e < a_0 n^2$) the difference between the energy of nonperturbed atomic state and corresponding Kramers - Henneberger (KH) state is shown to coincide with the Stark shift of atomic level.

Different mechanisms of the ionization suppression are found to take place and to change each other in dependence on laser intensity if the laser intensity exceeds some critical value.

The KH stabilization is found to appear when the atomic and KH potentials are rather close to each other ($\alpha_e < a_0 n^2$). In terms of free-atomic states the KH stabilization observed can be interpreted as the result of the interference of the direct one-photon transition to the continuum $|n\rangle \rightarrow |E\rangle$ and the three-photon bound-free transition via the intermediate continuum states $|n\rangle \rightarrow |E'\rangle \rightarrow |E''\rangle \rightarrow |E\rangle$.

In the strong field region the interference stabilization is found to occur and is confirmed by the Λ-type transitions observed between neighboring atomic bound states via the continuum.

The important role of V-type transitions is found to exist for the ionization dynamics for some definite values of laser pulse and initial atomic state parameters.

It should be mentioned all the mechanisms of the ionization suppression have the interference nature.

References.

1. Popov A.M., Tikhonova O.V., Volkova E.A, Laser Phys., **10**, 188 (2000).

Stabilization of atoms in ultra-strong laser fields, a reassessment

M. Gavrila

Institute for Theoretical Atomic and Molecular Physics at the
Harvard-Smithsonian Center for Astrophysics
Cambridge, MA 02138, USA, and
FOM-Institute for Atomic and Molecular Physics
1098 SJ Amsterdam, The Netherlands

We present a critical reassessment of intense-field atomic stabilization following severe criticism of the notion. New results are analyzed.

We first recall the basic notions regarding "quasistationary (adiabatic) stabilization" (QS), the original form in which the concept has emerged from high-frequency Floquet theory. QS designates the property of the high-frequency ionization rates to decrease with intensity beyond some critical high value of the latter. We then pass to "dynamic stabilization" (DS), which is the form of the phenomenon, covering the case of rapidly turned-on pulses. DS describes the fact that the total ionization probability of an atomic electron, at the end of a laser pulse of given shape and length, starts decreasing beyond a certain value of the peak intensity (albeit in an oscillatory manner). At still higher intensities a "destabilization" regime was discovered, in which the ionization probability increases slowly to 1. We present new results to document these regimes. Further, we give an interpretation of DS based on the expansion of Schroedinger wave packets in terms of Floquet states ("multistate Floquet theory").

We then comment on the controversy around DS in recent years, originating, on the one hand, in numerical results disagreeing with mainstream calculations, and, on the other, in results from mathematical physics. The experimental evidence is reassessed. Finally, perspectives are considered, theoretical and experimental. The advent of VUV-FEL light sources represents a milestone for the experimental study of the ground state stabilization of H.

Lorentz force effect in strong-field atomic stabilization

Mikhail Yu. Ryabikin and Alexander M. Sergeev

Institute of Applied Physics, Russian Academy of Sciences,
46 Ulyanov Str., Nizhny Novgorod 603600, Russia

E-mail: mike@ufp.appl.sci-nnov.ru, Fax: +7-8312-363792

The electron wave packet evolution at atomic ionization with a very intense laser pulse has been studied numerically beyong the dipole approximation in order to explore the suppression of atomic stabilization because of the Lorentz force exerted by the magnetic component of the incident field.

A two-dimensional model has been used, the x and z axes being chosen along the polarization vector of the linearly polarized electric field and the electromagnetic wave propagation direction, respectively. The electric field has been taken as a trapezoidal pulse with two-cycle linear ramps and ten-cycle flat top, the frequency being egual to 1 (in atomic units). An atom has been considered initially in the ground state of a smoothed 2D Coulomb potential, the ionization energy being equal to 0.5. The vector potential of the electromagnetic field has been expanded on z up to the linear term and an appropriate unitary transform has been made reducing the Schroedinger equation to the form suitable for using the split-step fast Fourier transform method.

The absorbing boundaries have been utilized and the probability of finding the electron inside the square of side L=100 a.u. around the atomic core just after the pulse turn-off has been used as a measure of an atom survival. Stabilization has been found to occur at field amplitudes $1.5<E<10$. At larger E a portion of the wave function leaks from an atom in the propagation direction. At $E>15$ the oscillating electron wave packet consists of two distinct parts. The first part, strongly localized in the vicinity of the atomic core, is stabilized in the superposition of Kramers-Henneberger bound states. The second part spreads and drifts away from an atom in z direction due to the Lorentz force. The stabilized fraction falls sharply with increasing laser field amplitude and becomes negligible at $E>22$. The similar "window" for efficient high-order harmonic generation in the Kramers-Henneberger stabilization regime has been also found.

Stabilization in photodetachment by ultrashort pulses

M. Dörr[†] and R. M. Potvliege[‡1]

[†]Max-Born-Institut, D–12489 Berlin, Germany
[‡]Physics Department, University of Durham, South Road, Durham DH1 3LE, UK

We have investigated the stabilization of a one dimensional model atom under the influence of a high frequency laser pulse of a few cycles duration, through both an *ab initio* numerical integration of the time-dependent Schrödinger equation and a Floquet calculation in the single-dressed-state approximation. Provided the intensity is not too high, the variation of the photodetachment probability is explained by adiabatic stabilization, despite the shortness of the pulse. On the other hand, if the intensity is sufficiently high, the electron behaves as if it were not interacting with the core. The probability that the atom is left ionized or in a given excited bound state then depends only on the extent to which the electronic wavepacket spreads out during the pulse; in particular, it does not depend on the frequency or on the peak intensity.

[1]e-mail: R.M.Potvliege@durham.ac.uk

ATOMIC PHOTOIONIZATION BEYOND THE DIPOLE APPROXIMATION

Luis Roso and J. R. Vazquez de Aldana
Departamento de Fisica Aplicada,
Universidad de Salamanca
37008 Salamanca, Spain

Atomic photoionization is studied without the use of the dipole approximation, i.e. taking into account the influence of the magnetic field component of the laser beam. This is studied in to different regimes.

The first part of the talk will be devoted to the presentation of a new analytical model, based on a local phase shift of the wave function, is presented that indicates the possibility to induce excitacion due to the magnetic fied without changing the space distribution of the electron charge density. In other words, we discuss the possibility of excitation/ionization just by modifying the phase of the wavefunction (of course, this is not a global phase change but a local one) [1 - 2]

The second part will be devoted to the numerical simulation of photoionization, for the case of a linearly polarized laser field, using a flat atom model that describes the dynamics of the electron in the plane determined by the electric field polarization axis and by the propagation axis in other words, the magnetic field is always perpendicular to the plane considered. Computing solutions of the time dependent Scrhödinger approximation, we are able to describe the drift (along the propagation direction) due to the magnetic field [3]. Along a collaboration between Salamanca, Imperial College and Durham, we have observed that this drift is much more important than expected [4], and it pushes the electron out of the "dipole trajectory" that passes above the nucleus many times. This observation is relevant for the study of high frequency atomic stabilization and for the validity of the KH-type models. Our conclusion is that magnetic field drift along the propagation axis can destroy stabilization for relevant regions of parameters.

[1] J R Vazquez de Aldana and Luis Roso, Physical Review A (April 2000)
[2] J R Vazquez de Aldana and Luis Roso, Physical Review A (May 2000)
[3] J R Vazquez de Aldana and Luis Roso, Optics Express 1999, find it at http://epubs.osa.org/oearchive/source/11811.htm.
[4] N J Kylstra, R A Worthington, A Patel, P L Knight, J R Vazquez de Aldana and L Roso, submitted to Phys Rev Letters

Coherent Control of Quantum Dynamics in Strong Laser Fields

Philip H. Bucksbaum
Department of Physics, Randall Laboratory
University of Michigan, Ann Arbor, MI 48109-1120

This is a summary of recent efforts to control quantum dynamics in condensed phase and gas phase systems, using shaped ultrafast radiation. Systems under study range from electron wave packets in atoms, to chemical dynamics in molecular liquids and lattice dynamics in crystalline solids. The common feature of all of these systems is their ultrafast response. Shaped intense ultrafast radiation initiates the dynamics, which can then be studied using several new techniques.

Among the systems that we have studied in this way are Rydberg wave packets. We have devised several interference techniques based on ultrafast shaped optical pulses or half-cycle terahertz radiation to map the phase evolution of these simple systems.

Molecules are more challenging than atomic Rydberg states because control can be used to channel the dynamics into different final state channels such as dissociative vs. non-dissociative ionization. We have studied evolutionary algorithms that optimize the pulse shape for either of these channels.

Liquids are still more challenging. Here, coherent excitation always competes with rapid decoherence in the liquid environment. We have used strong fields to help overcome this, along with new Genetic Algorithms that efficiently search phase space for non-obvious solutions. We have achieved mode-selective excitation in this way.

Finally, ultrafast excitation of the electronic bands in a crystalline solid can create coherent lattice motion corresponding to the generation of coherent acoustic or optical phonons. We are studying these using ultrafast x-rays.

Many students and colleagues are engaged in these experiments. We particularly acknowledge David Reis, Matt DeCamp, Marc Hertlein, Tom Weinacht, Jae Ahn, Brett Pearson, Emily Peterson, Catherine Herne, John Caraher, and James White. The National Science Foundation and the Department of Energy provide funding for this research..

Author: E.A. Shapiro

Affilation: General Physics Institute, Russian Academy of Sciences

Address: General Physics Institute RAS, 38 Vavilov
St., Moscow, 117942 Russia. fax: (7-095)135-1140. e-mail:
zheka@gon.ran.gpi.ru

Title: "Patterns of localization of Rydberg wave packets."

Abstract: "We suggest a uniform method to describe localization of quantum wave packets. This method is based on the use of classical action-angle variables. From this single viewpoint, we describe various Rydberg wave packets that arise in 2D and 3D Coulomb problems. In particular, spatial structure of the well-known angular Rydberg wave packets is clarified."

Photoionization of Rydberg atoms in interference stablilization regime: influence of initial distribution of atomic population

M.V. Fedorov and N.P. Poluektov
General Physics Institute, Russian Academy of Sciences
38 Vavilov St., 117942 Moscow, Russia

Interference stabilization of Rydberg atoms, which has been studied thoroughly since late 1980s [1-9], is recognized to occur due to whether Raman-type transitions via continuum (of so called Λ-type), or transitions via lower resonant atomic levels (V-type transitions). If one treats the problem of Rydberg atom stabilization in terms of quasienergies and quasienergy states, then, as it has been shown in multiple papers [5-9], in the case when V-type transitions channel is open different quasienergies have different ionization widths, and, therefore, show different resistance to photoionization. This leads to an assumption that atoms with different initial population will behave differently in the laser field. (Atom with initial population coinciding with the state matching narrower quesienergy level decays slower than the one with the population close to the state of a broader quasienergy level).

We have verified this assumption [10], and detected the substantial dependence of the photoionization probability of Rydberg atom on its initial superposition state. Moreover, we have derived the conditions under which the atomic electron can stay almost completely trapped on the bound levels, no matter how durable and intensive the laser impulse is. It is shown that phase features of the initial coherent population of Rydberg levels and the ionization yield can be efficiently controlled in a scheme of ionization by two (pump-probe) identical laser pulses with a varying delay time τ_d between them. If an atom is excited initially to some Rydberg level E_{n_0} (here n_0 is the principal quantum number), the first pulse provides efficient re-population of this and neighboring levels E_n. A mechanism of re-population consists of Raman-type transitions via lower-energy resonance level (transitions of V-type). If the pulse duration is long enough, by the end of the first pulse all the quasienergy states of an atom except the one of zero width in the field decay. Then, depending on the delay between two pulses, the second pulse whether ionizes the atom completely (if $\tau_d = T_k/2$, T_k – the Kepler period), or leaves the atomic population unchanged (if $\tau_d = T_k$).

Experimental conditions under which the effect of electron's yield dependence on initial population distribution can be, for instance, the following: $n_0 = 25$, $\omega = 1{,}7\times10^{14}$ sec^{-1}, $F_0 = 6\times10^5$ V/cm ($I = 1\times10^9$ W/cm^2), $\tau = 50\cdot T_k = 120$ ps. (Here ω, F_0 and I are respectively laser frequency, field-strength and intensity, τ is the duration of each laser pulse.)

References

1. M.V. Fedorov and A.M. Movsesian, J. Phys. B, **21**, L155 (1988).
2. L. Noordam, H. Stapelfeldt, D.I. Duncan, and T.F. Gallagher, Phys. Rev. Lett., **68**, 1496 (1992).
3. J.H. Hoogenraad, R.B. Vrijen, and L.D. Noordam, Phys. Rev. A, **50**, 4133 (1994).
4. M.Yu. Ivanov, Phys.Rev.A, **49**, 1165 (1994).
5. A.Wojcik and R.Parzinski, Phys. Rev. A, **50**, 2475 (1994).
6. A.Wojcik and R.Parzinski, J.Opt.Soc.Am.B, **12**, 369 (1995).
7. M.V. Fedorov and N.P. Poluektov, Laser Physics, **7**, 299 (1997).
8. M.V. Fedorov and N.P. Poluektov, Optics Express, **2**, 51 (1998).
9. N.P. Poluektov and M.V. Fedorov, JETP, **87**, 445 (1998).
10. M.V. Fedorov and N.P. Poluektov, Optics Express, **6**, 117 (2000).

Quantum Interference Effects in Above-threshold Ionization

G.G. Paulus, F.Grasbon and H.Walther
Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany
email: ggp@mpq.mpg.de fax: ++49 89 32905 200

In the 20 years since above-threshold ionization (ATI) was discovered, our understanding of this phenomenon has undergone a remarkable evolution. With the advent of high-repetition rate femtosecond laser systems the investigation of high-energetic photoelectrons became feasible. This let to the discovery of the ATI plateau, very much resembling the plateau in high-harmonic generation (HHG). Of particular importance for an intuitive picture of ATI has been the development of a classical model of strong-field laser-atom interaction. However, it has also been noticed, both theoretically and experimentally, that the envelope of the ATI (as well as HHG) spectra has some additional structure, namely minima at various energies.

Unfortunatelly, in the experiment the contrast of the minima is rather low due to the intensity distribution in the focus. In order to investigate the structure in the envelope of ATI spectra, we used elliptically polarized light and a high repetition rate laser. By varying the ellipticity of the laser polarization, the contrast of interference structures can be kept high over an extended energy range of the plateau ATI electrons. The high repetition rate is important to reduce statistical noise. At present, we use a Ti:Sapphire femtosecond laser system with a repetition rate of 100 kHz. It delivers 50 fs pulses at a wavelength of 800 nm. Intensities up to $1.5 \cdot 10^{14}\,\mathrm{W/cm^2}$ can be reached. The photoelectrons are analyzed with a time-of-flight spectrometer capable of recording several electrons per laser shot.

We measured angular distributions of the photoelectrons with elliptical laser polarization. The measurements show the well-known deviation from 4-fold symmetry for the low-energy electrons. The distribution of the high-energy electrons also lacks the 4-fold symmetry, however, its appearance differs clearly from the low-energy electrons. This can easily be traced back to the different origin of the symmetry breaking in both cases: For the low-energy electrons it is essentially the atomic or ionic potential that distorts the angular distribution, since electrons drifting away at angles symmetric to e.g. the big axis of the polarization ellipse experience the atomic potential differently. The plateau electrons on the other hand stem from rescattering at the ion core during the ionization process. It is the asymmetry in the return times that causes the asymmetry in the angular distribution of the plateau electrons.
Besides these classical effects, there are also features which can only be described with quantum models. The most eye-catching one is that the plateau is split or, in other words, there is a second plateau at a slightly different angle. The high sensitivity of our experiment allows us to investigate the plateaus beyond the classical cut-off at $10\,U_\mathrm{P}$, where U_P is the ponderomotive energy. It is not possible to explain the splitting of the plateau in terms of classical electron trajectories, because there is only one trajectory left at $10\,U_\mathrm{P}$. This is different for the quantum calculation and thus interference is possible. The gap between the two plateaus can be explained as destructive interference of electron trajectories.

Experimental evidence for dynamic Raman processes on the rising and falling edges of intense laser pulses

J H Posthumus

Sektion Physik, Universität München, Am Coulombwall 1, 85748 Garching, Germany

L J Frasinski and K Codling

J. J. Thomson Physical Laboratory, The University of Reading, Whiteknights, Reading RG6 6AF, UK

The Raman effect is a well-known example of laser-molecule interaction which changes the state of a molecule without the absorption or emission of a net number of photons. During a Stokes transition, for example, a photon scatters inelastically and excites the molecule to a higher vibrational level. Whereas the regular Raman effect is explained in terms of the unperturbed energy levels, a sufficiently intense laser field will change the levels considerably. Frequently, these changes are described in terms of adiabatic, field-dressed states. The adiabatic curves, which outline the electronic energy as a function of internuclear distance, are characterised by avoided crossings (gaps), whose separations depend on the laser intensity.

During below-threshold dissociation (BTD), the H_2^+ molecule dissociates by the net absorption of 1 photon, even though the energy of this photon is insufficient to overcome the molecular binding energy [1]. This intense field process is enabled by an upward shift of the pertinent adiabatic energy level on the falling edge of the laser pulse. In our experiment, H_2 molecules were subjected to intense laser pulses at λ = 800 nm and of 45 – 500 fs duration [2]. The observed shift of a low energy proton peak as a function of pulse length is interpreted as evidence of BTD.

At shorter wavelengths, vibrational trapping in the laser-induced potential well above the one-photon gap is likely to occur. If the laser intensity increases further, the gap grows larger and thus the well becomes shallower. A trapped, vibrational wavepacket can therefore partially escape as the bottom of the well is pushed upwards, on the rising edge of the laser pulse [3]. An examination of the adiabatic curves indicates that no net number of photons is absorbed by the H_2^+ ion in this process, and hence the term zero-photon dissociation (ZPD). We have observed near-zero energy protons at λ = 266 and 400 nm and interpret these as experimental evidence of ZPD [4].

[1] R Numico, A Keller and O Atabek, Phys. Rev. A **56** 772 (1997)

[2] L J Frasinski et al, Phys. Rev. Lett. **83** 3625 (1999)

[3] A Giusti-Suzor and F H Mies F H, Phys. Rev. Lett. **68** 3869 (1992)

[4] J H Posthumus et al, to be published

Energetic particles generation in nanostructured solids

A.B.Savel'ev, S.A.Gavrilov, D.M.Golishnikov, V.M.Gordienko, P.M.Mikheev, A.A.Shashkov, T.V.Vlasov, and R.V.Volkov

International Laser Centre & Physics Faculty, M.V.Lomonosov Moscow State University, Vorobyevy gory, Moscow 119899, Russia; Phone:+7(095)9395315; Fax:+7(095)9393113; E-mail:savelev@femto.ilc.msu.su

Nanostructured solids exhibit peculiar behaviour under interaction withsuper intense femtosecond laser pulses [1,2]. Having near solid statemean density, they at the same time consist of small, few nanometer indiameter particles separated by the void, that is somehow similar to thecluster jet [3]. Hence, the plasma created in such a nanostructuredtarget is dense and hot as in the case of a bulk targets, and providesfor much more efficient generation of hot electrons, fast ions, etc. as it has been proved for cluster jet target.

In this paper we discuss different experimental data and theoretical aspects concerning interaction of super intense femtosecond laser pulses with nanostructured targets. We describe our results on intensity and wavelength dependence of hard x-ray yield from plasma, and deduced from this hot electron temperature dependence on these parameters. We report on efficient hard x-ray production from highly porous silicon, and dependence of the yield on contrast and duration of laser pulses. Experimental evidence for increase in both hot electron number and « temperature" are presented. We are also discussing our results on time-of-flight analysis of fast ions expelled from plasma and peculiarities of their angular distribution in the case of nanostructured solids.

Theoretical consideration of laser-plasma interaction includes both intracluster and intercluster processes, such as Coulomb expansion, plasma jet collisions, hot electrons production, etc.

The feasibility to observe D-D fusion in nanostructured solids is also being discussed. This arises from the fact, that clusters explosion leads to formation of multiple ion jets. Ions energy could be far above 1 keV - the value enough to produce efficient D-D fusion. Different possibilities to create D-enriched nanostructured solids will be discusses as well.

1. R.V.Volkov, V.M.Gordienko, M.S.Dzhidzhoev, et.al., Quantum Electronics, 27, 1081 (1997).
2. V.M.Gordienko, A.B.Savel'ev, Uspekhi Fizicheskih Nauk, 169, 78 (1999).
3. T.Ditmire, Contemporary Physics, 38, 315 (1997).

Rare gas cluster explosion in a strong laser field

Kenichi Ishikawa and Thomas Blenski

CEA-Saclay, DSM/DRECAM/SPAM, Bât. 522, 91191 Gif-sur-Yvette Cedex, France
e-mail: ishikawa@cea.fr, phone: +33-169085888, fax: +33-169088707

There has been growing interest in the study of intense laser interaction with atomic and molecular clusters for several years. Although the global density of a cluster gas may be arbitrarily low, its high local density leads to strong absorption of laser energy. Experiments have revealed high energetic nature of the interaction [1].

We report the results of our Monte Carlo particle dynamics simulations of rare gas cluster explosion in a strong laser field. The equations of motion of the ions and the free electrons are numerically integrated with the force calculated as the sum of the contributions from the laser field and real Coulomb potentials of the other particles. Free electrons may appear through tunneling ionization and electron impact ionization, and may recombine with ions. This method allows us to follow the motion of both ions and free electrons during the cluster explosion.

In our results, the dependence of ion kinetic energy on its charge state is approximately quadratic up to a certain value and linear for higher charge states. Such a behavior was also observed in experiments by Lezius *et al.* [2], who attributed the former to Coulomb explosion and the latter to hydrodynamic expansion. Our analysis of the simulation results, however, shows that this behavior can be entirely explained based on Coulomb explosion mechanism.

Our results also show that electron impact ionization plays only a minor role in the production of highly charged ions and support the ionization ignition model by Rose-Petruck *et al.* [3].

References

[1] T. Ditmire, T. Donnelly, A. M. Rubenchik, R. W. Falcone, and M. D. Perry, Phys. Rev. A **53**, 3379 (1996).

[2] M. Lezius, S. Dobosz, D. Normand, and M. Schmidt, Phys. Rev. Lett. **80**, 261 (1998).

[3] C. Rose-Petruck, K. J. Schafer, K. R. Wilson, and C. P. J. Barty, Phys. Rev. A **55**, 1182 (1997).

Clusters in intense laser pulses

E. Suraud[1], P. G. Reinhard[2]

[1)] Lab. Physique Quantique, Université P. Sabatier
118 Rte de Narbonne, 31062 Toulouse, cedex, France
[2)] Institut für Theoretische Physik, Universität Erlangen,
Staudtstrasse 7, D-91058 Erlangen, Germany

We discuss the response of clusters subject to intense laser fields in the framework of a time dependent DFT approach which allows a fully non adiabatic treatment of both electronic and ionic degrees of freedom.. Most results have been obtained for simple metal clusters. We show in this case the importance of the plasmon resonance in the electronic response. We also consider the impact of ionic motion on the ionization of these metal clusters. We show in particular that for long enough pulses, ionic expansion can drive the system into resonance with the electronic plasmon resonance, which leads to a strongly enhanced ionization. We next consider the case of hydrogen clusters, in relation to recent experiments on fusion from irradiated deuterium clusters. We analyse the response of small to medium size hydrogen clusters to moderately intense lasers with intensities up to typically a few $10^{15} W.cm^{-2}$. A comparison between hydrogen and sodium resposnes is furthermore performed.

References

[1] P.-G. Reinhard, E. Suraud, J. Clust. Sci. **10**, 239 (1999)

[2] C.A. Ullrich, P.-G. Reinhard, E. Suraud, J. Phys. B **30**, 5043 (1997)

[3] P.-G. Reinhard, E. Suraud, Euro. Phys. J. **D3**, 175 (1998)

[4] F. Calvayrac, P.-G. Reinhard, E. Suraud,C.A. Ullrich, Phys. Rep. in press

Circular and Elliptic Dichroisms in Laser Interactions with Unpolarized Targets

N. L. Manakov

Voronezh State University, 394693, Voronezh, Russia
Fax: 7(0732)789755; E-mail: manakov@thp.vsu.ru

Circular Dichroism (CD) effects are typical for photoprocesses with magnetic solids or chiral molecules. Similar effects are well-known also for photoprocesses (e.g., the photoionization) with polarized atomic targets. In both cases the existence of CD is caused by time-odd pseudovectors (e.g., spins or angular momenta) inherent to the problem. In this paper the dichroism effects in strong laser field interactions with *unpolarized* atomic targets are reviewed, which have a physical origin different from the mentioned above. These effects originate from a specific interference between real and imaginary (skew-Hermitian or "dissipative") parts of quantum transition amplitudes or corresponding nonlinear susceptibilities.

We use the linear ($l = \mathbf{e} \cdot \mathbf{e}$) and circular ($\xi = i\hat{\mathbf{k}} \cdot [\mathbf{e} \times \mathbf{e}^*]$) polarization degrees for the description of the polarization state of an elliptically-polarized laser beam with an electric vector $\mathbf{F}(\mathbf{r}, t) = F\mathrm{Re}\{\mathbf{e}\ \exp[i(\mathbf{k} \cdot \mathbf{r} - \omega t)]\}$, where $\mathbf{e}$ is the unit (complex) polarization vector; $\mathbf{k} = \hat{\mathbf{k}}(\omega/c)$; $0 \le l \le 1$, $-1 \le \xi \le +1$, and $l^2 + \xi^2 = 1$. We deal with CD if the differential cross section (or anoter measurable parameter) of a, generally multi-color, multiphoton process, $d\sigma$, differs for right ($\xi = +1$) and left ($\xi = -1$) circular polarizations of *one* of the photons at linear polarizations of other photons (or, equivalently, $d\sigma$ differs at reversing signs of ξ-parameters for *all* photons involved into the photoprocess). In the presence of CD $d\sigma$ has the form:

$$d\sigma = d\sigma_{reg} + \xi\, f_{cd}. \tag{1}$$

In photoprocesses with identical photons (from the same laser beam) the Elliptical Dichroism (ED) is possible when $d\sigma$ has the form:

$$d\sigma = d\sigma_{reg} + l\,\xi\, f_{ed}. \tag{2}$$

This effect is nonzero only for elliptically-polarized photons with $0 < |\xi| < 1$.

The necessary conditions for the appearance of dichroisms and the general properties of CD and ED parameters, f_{cd} and f_{ed}, and their magnitude are analyzed for a number of processes both with the perturbative account of photon(s)-atom interaction (the scattering of optical and X-ray photons, two-photon excitation and ionization, frequency-mixing processes, *etc.*) and with the nonperturbative account of a strong laser field $\mathbf{F}(\mathbf{r}, t)$ (laser-assisted electron-atom scattering, above-threshold ionization and high harmonic generation). The peculiarities of dichroism effects induced by a dc electric field are discussed. We address also the question of the concurence between CD and ED effects in a currently explored scenario in which the atom is ionized in the presence of a strong laser field and of one (or several) of its higher harmonics.

This research is supported in part by Grants of INTAS-RFBR (No. 97-673)) and RFBR (No. 00-02-17843).

Acceleration of Free Electrons by a High-Intensity Laser Pulse

N.B. Narozhny[1] and M.S. Fofanov[2]

Moscow Engineering Physics Institute, Moscow, 115409, Russia
[1] *e-mail: narozhny@pc1k32.mephi.ru*
[2] *e-mail: fofanov@pc1k32.mephi.ru*

Acceleration of a free electron by a high-intensity laser pulse is studied theoretically. The dynamics of electrons is governed by fast time averaged equations of motion reported earlier in our paper [1]. It is shown that due to the ponderomotive effect electrons are scattered away from the pulse and can gain relativistic energies. Since the relativistic ponderomotive potential displays axial asymmetry [1] for the case of linear polarized laser pulse, the energy distribution of accelerated electrons is also asymmetric. These results are in agreement with experiment of G. Malka, E. Lefebvre, and J.L. Miquel [2].
This work was supported in part by the Russian Foundation for Basic Research (grants no. 00-02-16354, 00-02-17078).

References

[1] N.B. Narozhny and M.S. Fofanov, Zh. Exp. Teor. Fiz. **117**, (2000).

[2] G. Malka, E. Lefebvre, and J.L. Miquel, Phys. Rev. Lett. **78**, 3314 (1997).

Strong Field Seminar
Laser Physics 2000
Bordeaux, France

Abstract

New Results on Strong-Field-Accelerated Nuclear Beta Decay
H. R. Reiss, A. Shabaev, and H. Wang
Physics Department, American University, Washington, DC 20016-8058, USA
Telephone: 1-202-885-2749
Fax: 1-202-885-2723
E-mail: reiss@american.edu

The ultimate aim of this research is to develop a method to accelerate the radioactive decay rate of high-level nuclear fission wastes. To be useful for the disposal of high-level radwaste, the rate acceleration should be large, the physical process should be capable of being applied to large volumes of waste materials, and the method should offer the possibility of low cost in application. The basic physics of a non-nuclear means of doing this is the immediate goal of the research. The process is based on the interaction of intense, low frequency electromagnetic fields with nuclei. An effort along these lines was pursued about twenty years ago, but was abandoned for reasons that are now understood to be inappropriate.

The fundamental theory has been reworked in a much cleaner and more transparent fashion than the previous effort, and the basic physical mechanisms that provide coupling between a long wavelength field and the nucleus have been identified and clarified. There are three such mechanisms, and all are of a fundamentally strong-field (nonperturbative) nature with no counterparts at ordinary intensities of electromagnetic fields. There was much controversy at the time of the original publication in the 1980s. With the new understanding of the basic coupling mechanisms, it is now easy to show why alternative formulations proposed to study the process, in fact explicitly exclude all the fundamental mechanisms for decay rate enhancement.

There were several sets of experiments done in the early 1980s that gave positive results, but with magnitudes too small to be consonant with the contemporary understanding of the physics. Those experiments have now been re-examined, and the cause of the small rates is now understood. With that advance, the old experiments are now seen to be consistent with the theory, and can be regarded as "proof-of-principle" experiments. That is, existing experiments support the expectation of important acceleration of the decay of high-level radioactive waste.

Seminar 3
Physics of Cold Atoms

Monday, July 17, 2000

Chair: W. Schleich (Germany) **Session 3.1**

11.00 -11.45 I. Bloch (Munich, Germany)
Phase coherence of Bose-Einstein condensates and coherent control of atom laser beams

11.45-12.10 V.A. Alekseev, D.D. Krylova (Moscow, Russia)
Condensate fraction of slightly nonideal Bose gas in a parabolic trap

12.10-12.35 F. Chevy (Paris, France)
Vortices in Bose-Einstein condensates

12.35-13.00 K.V. Krutitsky, J. Audretch (Konstanz, Germany)
Local-field effect in atom optics of two-component Bose-Einstein condensates

13.00-14.00 Lunch

Chair: C. Salomon (France) **Session 3.2**

14.00-14.45 D. Heinzen (Austin, USA)
Atom-molecule coupling in a Bose-Einstein condensate: a new form of chemistry?

14.45-15.10 Y.E. Lozovik (Troitsk, Russia)
Bose condensation, superfluidity and quasi-one-dimensional alignment of atoms with induced dipoles

15.10-15.35 M. Weitz (Garching, Germany)
Frequency independent laser cooling of atoms and molecules

15.35-16.00 V.I. Yukalov, E.P. Yukalova (Dubna, Russia) and V.S. Bagnato (Sao Paulo, Brazil)
Non-ground -state condensates of ultracold trapped atoms

16.00-16.30 Coffee Break

Chair: A. Weis (Germany) **Session 3.3**

16.30-17.15 V.S. Bagnato, L.G. Marcassa, P. Courteille, D. Felinto, S. Vianna (Sao Paulo, Brazil)
Observation of bifurcation in the spatial distribution of cold trapped atoms

17.15-18.00 K.A.H. van Leeuwen, A.E.A. Koolen, H.C.W. Beijerinck (Eindhoven, The Netherlands)
Slow beam atom optics: fun with atom waves

18.00-18.25 S. Meneghini, I. Jex, M.R. Kasimov, W.P. Schleich, V.P. Yakovlev (Ulm, Germany)
A laser beam as a beam-splitter for atomic waves

Tuesday, July 18, 2000

Chair: P. Pillet (France) **Session 3.4**

11.00-11.45 M. Raizen (Austin, USA)
Controlling atomic motion with optical dipole potentials

11.45-12.10 H. Ritsch (Innsbruck, Austria)
Collective laser cooling in multimode optical resonators without spontaneous emission

12.10-12.35 M.W. Mancini, R.A. Zanon, A.L. de Oliveira, K.M.F. Magalhyes, V.S. Bagnato, L.G. Marcassa (Sao Paulo, Brazil)
Direct observation of fine structure changing collisions in cold trapped ^{85}Rb

12.35-13.00 V. Gomer, D. Frese, B. Ueberholz, S. Kuhr, D. Meschede (Bonn, Germany)
Countable atoms in a dipole trap

13.00-14.30 Lunch

Chair: V. Bagnato (Brazil) **Session 3.5**

14.30-15.15 A. Weis, D. Giel, D. Nettels (Bonn, Germany)
Motion of vapor atoms studied by optical magnetic resonance tomography

15.15-15.40 S. Maniscalco, A. Messina, A. Napoli, K. Wang (Palermo, Italy)
QND Measurement of the vibrational energy of an ion in a 2D trap

15.40-16.05 Y. Sortais (Paris, France)
Recent progress on cold atom clocks

16.05-16.30 S.N. Andrianov, V.V. Samartsev (Kazan, Russia)
Anti-Stokes regime of laser cooling of solids dopped by rare-earth ions

16.30-17.00 Coffee Break

Chair: K.A.H. van Leeuwen (The Netherlands) **Session 3.6**

17.00-17.45 P. Pillet (Orsay, France)
Experiments and prospects for ultracold molecules

17.45-18.10 A.V. Taichenachev, A.M. Tumaikin, V.I. Yudin (Novosibirsk, Russia)
Optical, magneto-optical and geometric forces on atom in a near-resonance monochromatic field: Analytical results

18.10-19.00 Free Discussion

Phase coherence of Bose-Einstein condensates and coherent control of atom laser beams

Immanuel Bloch, Michael Köhl, Markus Greiner, T. W. Hänsch and T. Esslinger

Max-Planck-Insitute for Quantum Optics, Hans-Kopfermann-Straße 1,
D-85748 Garching, Germany
and
Sektion Physik, LMU München, Schellingstr. 4/III, D-80799 Munich, Germany
Phone: ++49-89-2180-3704, Fax: ++49-89-285192
Email: imb@mpq.mpg.de

Bose-Einstein condensates and atom lasers show fascinating interference phenomena on a macroscopic scale. The formation of an interference pattern depends fundamentally on the phase coherence of the system, which can be quantified by the spatial correlation function. Phase coherence over a long range [1,2,3] is the essential factor underlying Bose-Einstein condensation and related macroscopic quantum phenomena, such as superconductivity and superfluidity. Here I will report on the direct measurement of the first order spatial correlation function of a weakly interacting Bose gas. Using a radio-wave field with two frequency components we effectively create a double slit for magnetically trapped atoms. The spatial correlation function of the system is determined by evaluating the visibility of the interference pattern of two matter waves originating from the spatially separated 'slit' regions of the trapped gas.

In the second part of my talk I will discuss the realization of new atom optical elements based on stimulated hyperfine Raman transitions in magnetic fields. We were able to demonstrate a mirror, a beamsplitter and a resonator for the coherent matter wave of an atom laser beam by using Raman lasers with only a few milliwatts of laser power. Furthermore atoms can be easily accelerated or decelerated with this technique such that their de Broglie wavelength is continuously tunable over several orders of magnitude. This novel technique may open the path for new interferometer geometries with atom lasers or play an important role in the use of atom lasers in future atomic clocks.

Condensate fraction of slightly nonideal Bose gas in a parabolic trap.

V.A. Alekseev, D.D. Krylova

P.N. Lebedev Physical Institute, Russian Academy of sciences, 117924 Moscow, Russia

e-mail: valeks@sci.lebedev.ru

We calculated the corrections to the energy levels of the ideal gas in a parabolic trap to the first order in the coupling constant a (scattering length), and used the thermodynamic perturbation theory to find the temperature dependent corrections to the ideal gas ground state population n_0^0 [1]. To the first order in a it has a form

$$n_0 = n_0^0 - gt^2 \frac{(n_0^0)^2}{(n_0^0)^2 + \gamma t^3 N}\left[n_0^0 + \delta t^{3/2} N^{1/2}\right], \qquad (1)$$

where $g \approx 2.3(a/R)N^{2/3}$, $R = (\hbar/m\omega)^{1/2}$ is the harmonic oscillator length, $\omega = (\omega_x \omega_y \omega_z)^{1/3}$, $\omega_{x,y,z}$ are the oscillator frequencies, m is the atomic mass, $\gamma \approx 1.37$, $\delta \approx 1.74$, N is the number of atoms, $t = T/T_c$, T is the gas temperature and T_c is the critical temperature. We also found the new expression for the ideal gas ground state population

$$\frac{n_0^0}{N} = \frac{1}{2}\left[1 - t^3 + \sqrt{(1-t^3)^2 + 4\gamma t^3 / N}\right], \qquad (2)$$

which describes the rounding of phase transition in the vicinity of critical temperature. Eq.(2) gives the new criteria of thermodynamic limit $n_0^0 >> \sqrt{N}$. In this limit Eq.(1) takes a form

$$n_0 = n_0^0(1 - gt^2), \quad n_0^0/N = 1 - t^3 >> 1/\sqrt{N}. \qquad (3)$$

The temperature dependent corrections to the condensate fraction to the lowest order in a given by the Eqs.(1) and (2) are in contradiction with that found in the framework of mean field theory [2]

$$\Delta T_{\text{int}}/T_c = -1.3(a/R)N^{1/6}, \qquad (4)$$

where ΔT_{int} is the shift of the critical temperature caused by interaction [2]. In the thermodynamic limit the correction to the condensate fraction $\Delta n_0 = n_0 - n_0^0$ in Eq.(3) is more than $\sqrt{N}$ times larger, than given by Eq.(4). On the other hand, the correction Δn_0 in Eq.(1) tends to zero in the vicinity of T_c and does not change the critical temperature.

1. V.A.Alekseev, D.D.Krylova, *Sov. J. Quantum Electron.* 30(5), (2000), to be published.

2. S.Giorgini, L.P.Pitaevskii, S.Stringari, *Phys.Rev.*, A54, R4633 (1996).

Local-field effect in atom optics of two-component Bose-Einstein condensates

K.V.Krutitsky and J.Audretsch

Fakultät für Physik, Universität Konstanz, Fach M 674, Konstanz 78457, Germany

Phone: +49-7531-883798, Fax: +49-7531-884266

E-mail: kostya@spock.physik.uni-konstanz.de

Starting from the first principles of QED we have developed the quantum theory of the interaction of a two-component ultracold atomic ensemble with the electromagnetic field of vacuum and laser photons. The main attention has been paid to the consistent consideration of dynamical dipole-dipole interactions in the radiation field.

The ensemble of ultracold atoms is assumed to be a mixture of two species of two-level atoms with the masses m_1, m_2, transition frequencies ω_1, ω_2, and matrix elements of the transition dipoles moments d_1, d_2. It is described in terms of vector fields $\psi_j(\mathbf{r},t) = \psi_{gj}(\mathbf{r},t)|g_j\rangle + \psi_{ej}(\mathbf{r},t)|e_j\rangle$, $j = 1,2$, where $|g_j\rangle$ and $|e_j\rangle$ are the vectors of the ground and excited states of the quantized atomic fields; ψ_{gj} and ψ_{ej} are annihilation operators of the atoms in the internal states $|g_j\rangle$ and $|e_j\rangle$, respectively.

Theoretical analysis, carried out under consideration of the local-field effect, in adiabatic approximation leads to the following system of Maxwell-Bloch equations:

$$i\hbar\frac{\partial\psi_{gj}}{\partial t} = \left\{-\frac{\hbar^2\nabla^2}{2m_j} + \frac{\hbar}{4\Delta_j}\frac{\left|\Omega_j^+\right|^2}{\left[1-\frac{4\pi}{3}\left(\alpha_1\psi_{g1}^\dagger\psi_{g1}+\alpha_2\psi_{g2}^\dagger\psi_{g2}\right)\right]^2}\right\}\psi_{gj} \quad ,$$

$$\nabla^2\Omega_j^+ + n^2k_L^2\Omega_j^+ = 0 \quad , j = 1,2,$$

where $\Omega_j^+ = 2\mathbf{d}_j\mathbf{E}_{mac}^+/\hbar$ is a Rabi frequency, $\alpha_j = -d_j^2/(\hbar\Delta_j)$ is the atomic polaribility of j-th component, $\Delta_j = \omega_L - \omega_j$ is the detuning, $k_L = \omega_L/c$ is a wave number of the external laser radiation, and the refractive index n is given by the Maxwell-Garnett formula.

We have shown that all equations which are used up to now for the description of the behaviour of an ultracold atomic ensemble in a radiation field, for instance, Gross-Pitaevskii equation, can be obtained from our general system of equations making use of different assumptions concerning the magnitude of the density. Different regimes of diffraction of the two-component atomic beams are investigated on the basis of our general system of equations.

K.V.K. would like to thank Alexander-von-Humboldt Stiftung for financial support

Atom-Molecule Coupling in a Bose-Einstein Condensate: a New Form of Chemistry?

Daniel J. Heinzen*

Dept. of Physics, The University of Texas at Austin, Austin, TX 78712 USA

Dilute gas Bose-Einstein condensation is revolutionizing low-temperature physics. In some respects, dilute gas condensates are similar to other quantum collective systems such as superfluid liquid helium, but there are important differences as well. One of the most important is that atoms in a dilute gas may bind together to form molecules, and that, in principle, these molecules may also form a condensate. We have studied the coupling between ^{87}Rb atoms in a dilute gas condensate and bound $^{87}Rb_2$ molecules that is induced by stimulated Raman free-bound transitions. This results in the formation of molecules in a specific ro-vibrational state that can be chosen by the Raman laser frequencies. The Raman transition rate exhibits a resonance lineshape with an extremely narrow width as small as 1.5 kHz. As a result of this narrow width, we are able to measure the molecule-condensate interactions. At present, the loss rate of the molecules in our experiment precludes us from observing a molecular condensate. However, we argue that for longer molecular lifetimes, the coherent, reversible formation of a molecular condensate should occur. Experiments to try to demonstrate this process are in progress. Such a process could be regarded as a new form of chemistry, in which the state of bonding of atoms is controlled to the maximum extent allowed by quantum mechanics.

* This work was carried out in collaboration with Roahn Wynar, Riley Freeland, Changhyun Ryu, Dian-Juin Han, and Daniel Comparat, University of Texas, Peter Drummond and Karen Kherunstyan, University of Queensland, and Boudewijn Verhaar and Servaas Kokkelmans, Eindhoven University of Technology. We gratefully acknowledge the support of the U. S. National Science Foundation, the NASA Microgravity Research Division, and the R. A. Welch Foundation.

Bose condensation, superfluidity and quasi-one-dimensional alignment of atoms with induced dipoles

Yu.E.Lozovik, Institute of Spectroscopy, Moscow reg., Troitsk,Russia; e-mail: lozovik@isan.troitsk.ru
Fax:+7 095 334 08 81

Laser-cooled and trapped atoms or molecules with electrical dipoles induced or aligned by an external field are considered. The influence of dipole-dipole interactions on Bose-condensation and superfluidity is analyzed. Phase diagram of the system is calculated. Rich variety of different alignments of dipoles ("molecules", "chains", liquid crystal and quasi-one-dimensional "crystal") versus temperature is analyzed.

Frequency Independent Laser Cooling of Atoms and Molecules

Martin Weitz

Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany,
and Sektion Physik der Universität München, 80799 München, Germany
e-mail: mrw@mpq.mpg.de

For many atoms, laser-cooling techniques can routinely provide ensembles with temperatures to the microkelvin regime. However, common laser-cooling techniques depend critically on the laser detuning from the atomic resonance frequency. This implies, that only single atomic species and isotopes can be cooled with one optical frequency. Moreover, systems with a richer internal structure, as complex atoms and all molecules have so far resisted laser cooling. Here, a novel scheme for laser-cooling is pointed out that is based on pulsed lasers with their broad frequency spectrum. The scheme relies on a matter wave interferometer where light pulses act as atomic or molecular beamsplitters [1]. The key point is that with a suitable pulse sequence, the probability of transferring photon momenta to a particle depends on its velocity, but not on the relative detuning from an absorption line. This allows the simultaneous laser-cooling of several different species or isotopes of atoms with similar transition wavelengths, and has prospects for the laser-cooling of molecules.

[1] M. Weitz and T. W. Hänsch, in *Laser Spectroscopy XII*; Europhys. Lett. **49**, 302 (2000).

Nonground State Condensates of Ultracold Trapped Atoms

V.I. Yukalov, E.P. Yukalova, and V.S. Bagnato

Bogolubov Laboratory of Theoretical Physics
Joint Institute for Nuclear Research, Dubna 141980, Russia

and

Instituto de Fisica de Sao Carlos, Universidade de Sao Paulo
Caixa Postal 369, Sao Carlos, Sao Paulo 13560-970, Brazil

A method of exciting nonground state Bose-Einstein condensates of trapped atoms is considered. The method is based on the resonance modulation of the trapping potential. The population dynamics of coherent modes is analysed.
The method makes it possible to create mixtures of different spatial modes in arbitrary proportions, including the formation of pure excited coherentmodes. Novel critical effects in the population dynamics are found.

Observation of Bifurcation in the Spatial Distribution of Cold Trapped Atoms

V. S. Bagnato, L.G. Marcassa, P. Courteille, D. Felinto* and S. Vianna*

Instituto de Física de São Carlos, USP

Caixa Postal 369, CEP 13560-970, São Carlos/SP, Brazil

Phone 55-16-2712012; Fax 55-16-2713616, e-mail: Vander@if.sc.usp.br

*Permanent address: Universidade Federal de Pernambuco

Ring shaped clouds in a MOT are formed when the Gaussian laser beams are misaligned such that they form a racetrack configuration. In this case, the forces acting on the atoms can be separated in two groups: i) Damping and trapping forces; ii) And vortex type force. The combination of the vortex type force together with the restoring force stabilizes the atomic trajectory, producing the ring-shaped trap. This model can justified the observed results in the Na experiment [1], where the number of trapped atoms is small. As the number of atoms is increased we must include the force due to secondary scattering of photons (F_{ss}) by the trapped atoms [2]. This force competes with the vortex force for large number of atoms ($N > 10^5$), and it can explain well the observed results in the Cs experiment [2]. In this work we explain the observation of bifurcation on the ring structure, combining the two previous models. The main importance of this report relies on the fact that the presence of collective behavior associated with the number of trapped atoms is the main cause of the sudden jumps from single to double ring distribution.

As an extension of the previously reported work [3], we observed in more detail the passage from a single to a double-ring structure. For this we employed a sodium-MOT loaded from a vapor. We observe a cloud of atoms about 1mm in diameter when the laser beams were well aligned. On the other hand, when the laser beams are misaligned, a ring shaped cloud mainly distributed on the XY-plane is observed. In the regime of low number of atoms and low light intensity, the observed that the ring is very stable and its study has already been reported [1,3,4]. However, at high laser intensity and high number of trapped atoms, the ring shaped cloud seems to become unstable at the end of the loading process. After some instability, the system evolves to a double-ring structure. In model, discussed above, N atoms are left to evolve in time as determined by their equation of motion. The results of the numerical integration of the equation of motion, shows that after a critical number of atoms, the radial atomic distribution evolves jumping from a single stable ring to a double stable ring. The external atoms are kept by an extra repulsion created by the atoms in the inner ring, pointing outward from the trap center. During our presentation, we shall present the experimental and theoretical results and the possibilities for its applications.

Financial Support: FAPESP, PRONEX.

[1] V.S. Bagnato et al, Phys. Rev. A 48, 3771-3775 (1993).
[2] T. Walker et al, Phys. Rev. Lett. 64, 408-411 (1990).
[3] M.T. Araújo et al, Phys. Rev. A 51, 4286-4288 (1995).
[4] I. Guedes et al, J. Opt. Soc. Am. B 11, 1935-1940 (1994).

Slow beam atom optics: fun with atom waves

K.A.H. van Leeuwen, A.E.A. Koolen, and H.C.W. Beijerinck
Department of Physics, Eindhoven University of Technology,
P.O. Box 513, 5600 MB Eindhoven, The Netherlands
phone: +31-40-2472550, fax: +31-40-2456050, e-mail: K.A.H.v.Leeuwen@tue.nl

Recently, an extremely precise atomic beam setup, optimized for quantum optics and atom optics experiments, has become operational in Eindhoven. In this machine, metastable helium atoms are first collimated by transverse laser cooling, and then decelerated to a uniform, low axial velocity in a Zeeman slower. Next, they are prefocused and subsequently funneled into a tiny, very intense parallel beam using two magneto-optic lenses. Finally, two small apertures (60 and 25 micrometer diameter), separated by two meters, are used to achieve extreme sub-recoil collimation of the beam in two dimensions. The resulting beam has a flux of 250 helium atoms in the metastable $\{^3S_1\}$ state per second. The axial velocity is 250 m/s with a measured rms spread of 3.8 m/s. The spread in transverse velocity is 9 mm/s. Thus, the beam can in many respects be considered as a true "plane atomic wave".

With this setup we have studied high-order Bragg scattering, in which a standing light wave acts like a coherent beamsplitter for the atomic wave. Thus, each atom in the beam is split in two "matter wave packets". Up to 8^{th} order Bragg scattering has been observed, while retaining full separation between consecutive Bragg orders. At 8^{th} order, the separation on the detector is more than 1 cm. The so-called "Pendellösung" oscillations in the splitting ratio have been studied in detail for 5^{th} order scattering.

As a demonstration of the precision of the setup, we have accurately measured the angular distribution of the spontaneous emission of light (dipole radiation patterns), simply by looking at the momentum recoil of atoms resulting from the emission of a single photon. As we have full control over the polarization and orientation of the excited atoms, the radiation patterns for σ- and π-polarized light could be observed separately.

The beam setup will be used for a variety of cavity QED and atom interferometry experiments. First experiments will include photon number measurements in a high-finesse optical cavity and quantum tomography of atomic (motional) wavepackets. An extension to the setup allows the study of a new type of continuously pumped single-atom laser, operating in the quantized cavity field regime.

The beamsplitter results open the way for a Mach-Zehnder type atom interferometer with true macroscopic separation between the arms. We plan to construct such an interferometer in the near future. It will be applied to a variety of precision measurements. The large path separation increases sensitivity for a number of applications (e.g., rotation and field gradient measurements) and allows easy separate access to the paths. The latter allows us to insert high-finesse cavities in either one or both of the arms. This offers fascinating new possibilities by the combination of atom interferometry and cavity QED.

A laser field as beam-splitter for atomic waves

S. Meneghini[(a)], I. Jex[(a,b)], M.R. Kasimov[(c)],
W.P. Schleich[(a)] and V.P. Yakovlev[(a,c)]

April 18, 2000

(a) Abteilung für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

(b) Department of Physics, FJFI ČVUT, Prague, Czech Republic

(c) Moscow State Engineering Physics Institute, 115409 Moscow, Russia

Abstract

We study the dynamics of atomic waves in two-dimensional light crystals formed by two crossing standing laser fields. The longitudinal modulation of the crystal with the Doppler frequency influences sufficiently the transversal spatial modulation of the atomic wave. Near the doppleron resonance the atomic density shows a fractional space period.

In this case a normal incident wave gives rise to an almost perfect conversion into the first momentum components and the light crystal acts as a highly efficient beam-splitter. The crossing angle, determining the Doppler frequency, is the easy-to-control parameter of the system.

In the next step we apply two sets of lasers to the atomic wave. The sets have different intensities to scatter atoms. In a STIRAP-like setup the first beam provides the force to push the atoms from the first to the second scattered transversal momentum component. At the beginning the atoms have no transversal momentum, the first component is not populated. The second set of lasers transfers the atoms from the original state to the first transversal momentum state. Since both laser fields have a large overlap the atoms are scattered from the orginial state to the second scattered state. This counter-intuitive setup similar to the STIRAP method works as a beam-splitter, too.

Controlling atomic motion with optical dipole potentials"

Mark G. Raizen
Department of Physics
The University of Texas at Austin

We report recent results and progress on the use of optical dipole potentials for quantum state preparation in the study of quantum chaos in mixed phase space, and for detection and feedback control of atomic motion.

Collective laser cooling in multimode optical resonators without spontaneous emission

Helmut Ritsch
Institut fьr Theoretische Physik
Universitдt Innsbruck
Technikerstr. 25, A-6020 Innsbruck, Austria.
Email: Helmut.Ritsch@uibk.ac.at, FAX: +43 512 507 2919

We propose a method to trap and cool many two-level atoms commonly coupled to driven high-Q cavity modes. The collective coupling of atoms to the field mode leads intracavity mode coupling and induces correlations between atomic motion and field dynamics, which can be used to extract kinetic energy from the particles via the cavity damping. For large detuning spontaneous emission plays no role and the cooling scheme works for all sorts of particles with sufficient dipole moment.

Direct observation of fine structure changing collisions in cold trapped ^{85}Rb

M. W. Mancini, R. A. Zanon*, A. L. de Oliveira**, K. M. F. Magalhães, V. S. Bagnato and L.G. Marcassa
Instituto de Física de São Carlos, Universidade de São Paulo,
Caixa Postal 369, 13560-970, São Carlos-SP, Brazil
Tel. 55-16-2712012, Fax 55-16-2713616
e-mail: mancini@if.sc.usp.br
Permanent address: * Universidade do Estado de Santa Catarina, ** Universidade Federal de São Carlos and Universidade do Estado de Santa Catarina.

Collisions between cooled and trapped atoms have been extensively investigated [1]. Exoergic collisions are specially important because they may result in loss of atoms from the trap. Two mechanisms contribute to the trap loss rate: radiative escape (RE) and fine structure changing (FSC) collisions. The two contributions are normally measured together (except in ^{7}Li [2] case, where FSC is not enough to eject atoms away, and therefore the losses are dominated by RE). There have been a few efforts to identify the FSC contribution to the total losses [3-6]. Here we report two different techniques to direct observe the atomic fragments originated from FSC. In a first experiment, $5P_{1/2}$ fragments in a Rb trap are detected through direct photoionization using a cw laser, in two steps. First atoms are excited with a dye laser from $5P_{1/2}$ to $8S_{1/2}$ state, second a Krypton ion laser excite $8S_{1/2}$ to continuum. To collect all atoms originated in $P_{1/2}$ within the Doppler profile, the probe laser for the first step is scanned and the ion signal integrated in frequency. The calibration procedure allows to obtain the loss rate due to FSC as $\beta_{FSC} \cong (4 \pm 2)\% \beta_T$.

In a second technique, the fragments are ionized using a nanosecond pulsed dye laser (1mJ/pulse, 4ns, $\Delta\nu = 0.2\text{cm}^{-1}$) pumped by the second harmonic of a Nd:YAG laser. The broad spectral range of the laser pulse overcomes the Doppler effect problem from the first technique, and a much better signal to noise ratio is obtained. Using this technique we measured β_{FSC} as a function of the trapping laser intensity, and detuning using a catalysis laser (Ti:Saphira-Coherent 899). The results show interesting dependencies. Comparison with existent theory is made.

References:

[1] J. Weiner et al., Rev. Mod. Phys. **71** (1999)
[2] N. W. M. Ritchie et al., Phys. Rev. A **51**, R890 (1995)
[3] L.G. Marcassa et al., Europ. Phys. J. D **7**, 317 (1999)
[4] A. Fioretti et al., Phys. Rev. **55**, R3999 (1997)
[5] J. P. Shaffer et al., Europ. Phys. J. D **7**, 323 (1999)
[6] H. Wang et al., Phys. Rev. Lett. **80**, 476 (1998).

Countable Atoms in an Optical Dipole Trap

V. Gomer, D. Frese, B. Ueberholz, S. Kuhr,W. Alt, D.Schrader, and D. Meschede
Institute of Applied Physics, University of Bonn, Wegelerstr. 8, D-531 15 Bonn, Germany

Tel: +49 (0)228-73-34-83, FAX: +49 (0)228-73-34-74, e-mail:
Gomer@iap.uni-bonn.de

For several applications in cavity quantum electrodynamics it is of interest to experimentally explore quantum interactions of a small and exactly known number of atoms. Full control of all internal and external atomic degrees of freedom is desirable in such applications, but cannot be achieved in a magneto-optical trap (MOT) due to its dissipative character. However, one can combine the operating convenience of the MOT for isolated atoms with the advantages for quantum manipulation offered by the nearly conservative potential of optical dipole traps [1]. Here we describe a simple experimental technique which allows us to store a small and deterministic number of neutral atoms in a dipole trap. We have also demonstrated the feasibility of a state-selective detection via resonance fluorescence at the level of a few neutral atoms.

We start with atoms stored in a MOT. Well separated equidistant steps in the fluorescence signal allow us to monitor the number of trapped atoms in a non-invasive way and in real time [2]. The dipole trap consists of a single focused Nd:YAG laser beam with a waist of 5 μm and a total power of 2.5 W which is superimposed on the MOT. To transfer these atoms into the dipole trap, the Nd:YAG laser is turned on a few ms before the MOT lasers are turned off. To recapture the atoms into the MOT, this procedure is reversed. The measured storage time of 51 s is limited by background gas pressure only. Atoms can be caught by the dipole trap only at places where the dipole potential exceeds the atomic kinetic energy. Even for small MOT sizes used in our experiments (typically 10 μm) the geometric loading efficiency should be about 70 %. However we are able to transfer every atom from the MOT into the dipole trap. The measured 100% loading efficiency clearly indicates that during few ms of simultaneous operation of both traps, the MOT effectively cools the atoms down into the dipole potential minimum.

Due to the large detuning of the dipole trap laser from atomic resonances the light shifts of both hyperfine ground states of Cesium are nearly identical. Still any initial preparation in a hyperfine state will be destroyed by off-resonant photon scattering from the dipole trap laser, yielding a relaxation of spin polarization. Using optical pumping we prepare the atoms in either F= 3 or F=4 state. For state-selective detection the MOT cooling laser is used while the MOT repumping laser remains blocked. As a result of the 3D-character of the MOT light field the atom decays within about 200 μs into another hyperfine state thus terminating the fluorescence signal. Even in this situation we are able to detect on average 3 fluorescence photons per atom on a stray light background of 0.5 photons. By varying the time between preparation of atoms in the dipole trap and probing we observed the relaxation of both hyperfine states towards an equilibrium. The measured long ground-state relaxation times of 4.2 s for F 4 and 3.3 s for the F 3 clearly show a strong suppression of the spontaneous Raman scattering due to destructive interference of scattering amplitudes far from resonance [3]. For a Cs atom in a Nd:YAG dipole trap Raman scattering is suppressed compared to the Rayleigh scattering rate by a factor of 90. Although the experiment described here is only sensitive to the change of the hyperfine F state, similarly long relaxation times are also expected for ail Zeeman m_F-sublevels.

The ability to load an exactly known atom number into an optical dipole trap opens a route to a novel kind of cold atom sources free of the indeterminism intrinsic to usual sources like atom beams. Together with recently demonstrated manipulation of motional states of atoms in standing-wave dipole traps [4], this system promises to be a new basis for future experiments with full control of all internal and external atomic degrees of freedom. One of the most interesting possibilities would be long-time localization of more than one atom within a mode of a high finesse cavity.

[1] R. Grimm, M. Weidemüller, Y.B. Ovchinnikov, Adv. At. Mol. Opt. Phys. **42**, 95 (2000)

[2] V. Gomer *et al.*, Phys. Rev. **A58,** R1657 (1998); V. Gomer *et al.*, Appl. Phys. B67, 689 (1998)

[3] R.A. Clime *et al.*, Optics Lett. **19,** 207 (1994)

[4] I. Bouchoule *et al.*, Phys. Rev. **A59,** R8 (1999); M. Morinaga *et al.*, Phys. Rev. Lett. **83**, 4037 (1999)

Motion of vapor atoms studied by optical magnetic resonance tomography

A. Weis ,D. Giel[1] and D. Nettels
Institut de Physique
Université de Fribourg
Chemin du Musée 3, 1700 Fribourg,
Switzerland
Tel +41-26-300 90 30, Fax +41-26-300 97 47
E-mail: Antoine.Weis@unifr.ch
research center caesar Friedensplatz 16,
53111 Bonn, Germany

Conventional magnetic resonance imaging (NMR tomography) cannot be applied to investigate low pressure gases because of the low density of spins in such samples. However, when the conventional technique is combined with optical methods for the creation of spin polarization and for the detection of the magnetic resonance transition one has a powerful novel technique . optical magnetic resonance tomography (OMRT) . which allows to study one-, two- and three-dimensional distributions of vapour phase atoms. In this paper we report on a quantitative, space and time resolved study of the diffusion of Cs atoms in a Ne buffer gas. By tomographically monitoring the time evolution of the shape of an initial spatially inhomogeneous magnetization we were able to make a precise measurement of the diffusion constant of Cs in Ne. In 2-dimensional magnetic resonance imaging a linear magnet field gradient ($\partial B_z/\partial x$, $\partial B_z/\partial y$) is superposed onto the main magnetic field B_z of a magnetic resonance apparatus. A spatial distribution of magnetization then yields a distribution of Larmor frequencies which, in practice, is obtained from the Fourier transform of the free induction decay (FID) of the transverse magnetization created by applying a radio-frequency $\pi/2$-pulse to the initial longitudinal magnetization. By rotating the gradient field (at constant magnitude) a series of projections of the magnetization are recorded which allow to reconstruct the full initial distribution. In our experiments the initial magnetization is created by an optical pumping pulse of a circularly polarized laser beam illuminating the sample (a quartz cell of 1 cm^3 containing Cs and Ne) through a small circular aperture in a mask. The $\pi/2$-pulse is applied after the light pulse and the decay of the precessing transverse magnetization is recorded via the paramagnetic rotation of the polarization of a probe laser beam propagating at right angles to the pump beam. The Fourier transform of the FID then yields the distribution of magnetization. In order to study diffusion the $\pi/2$ pulse is delayed by a variable time τ_D after the pump pulse. By comparing the shapes of the distributions as a function of τ_D with model calculations based on numerical solutions of the diffusion equation with cubic boundary conditions the diffusion constant Cs in Ne can be inferred.

TITLE: QND Measurement of the vibrational energy of an ion in a 2D trap

AUTHORS: S. Maniscalco, A. Messina, A.Napoli and K. Wang*

AFFILIATION: Dipartimento di Scienze Fisiche ed Astronomiche dell'Universita' di Palermo

* Department of Physics Beijing Normal University, Beijing, 100875 China

ADDRESSES: Dipartimento di Scienze Fisiche ed Astronomiche, via Archirafi 35, 90123 Palermo, Italy

TELEPHONE/FAX: ++390916234243

EMAIL: messina@fisica.unipa.it

ABSTRACT:
Quite recently it has been proposed a quantum non demolition measurement of the motional energy of an ion confined in a 1D trap [1].
In this paper we present an extension of this method to the bimodal case. Our treatment generalises the unidimensional one in a nontrivial way. In fact the quantum non demolition coupling induced by two properly configured laser beams is found to be crucially dependent on their phase difference. This means that, in the bidimensional case, the phase difference between the two laser beams plays the role of an adjustable external parameter which allows to optimise the measurement scheme itself, in terms of precision and sensitivity.
As in the one dimensional case, our proposal leads to interesting applications as, for example, cooling and preparation of arbitrary bimodal Fock states.
A relevant aspect of our scheme is that, due to the occurrence of Rabi frequencies degeneracy relative to different vibrational states, it is relatively simple to engineer classes of entangled vibrational states as, for instance, pair coherent states and maximally entangled superpositions of Fock states.
The practical feasibility of the method is brought to the light and briefly discussed.

[1] R.L. de Matos Filho and Vogel, Phys. Rev. A 76, 4520 (1996)

ANTI-STOKES REGIME OF LASER COOLING IN SOLIDS DOPED BY THE RARE-EARTH IONS

V.V.Samartsev, S.N.Andrianov

Kazan Physical and Technical Institute of RAS

10/7 Sibirsky Trakt Str., Kazan, 420029, Tatarstan, Russia

phone: (8432)763681; fax: (8432)765075; e-mail: samartsev@dionis.kfti.kcn.ru

This report is devoted to the problem of the laser cooling of solids. The anti-Stokes regime of such cooling is discussed in details. The special attention is spared to the laser cooling of solids doped by rare-earth ions (Tm^{3+}, Pr^{3+}, Dy^{3+} et.al.). Accordingly A.Kastler (J.Phys.Radium, v.11, 255, 1950), the rare-earth ions in transparent solids may be especially suitable as impurity centers centers promoting, due to their high quantum efficiency, for realization of the laser cooling process. The experimental results of R.Epstein with collaborators (Nature, v.377, 500, 1995) are described by means of the method of nonequilibrium statistical Zubarev-Peletminsky operator. The superradiant regime of laser cooling of solids is analyzed in details. The possibility of laser cooling of crystals doped by non-Kramers rare-earth ions is also discussed in this report.

Experiments and prospects for ultracold molecules:

Pierre Pillet

Laboratoire Aimé Cotton, CNRS II, Bât. 505, Campus d'Orsay, 91405 Orsay cedex, France

In contrast to atoms, laser cooling of molecules is very difficult because of the lack of a closed two-level scheme for recycling the population. The molecular photoassociation of cold atoms is one of the alternatives for the formation of cold molecules. In a photoassociation process, two colliding cold atoms absorb one photon to form a cold molecule in a ro-vibrational level of a molecular electronically excited state. Unfortunately, for most of the considered systems, photoassociated excited molecules dissociate after spontaneous emission. Long-range states below the first excited dissociation limits 6s+6p of the cesium dimer present configurations with Condon points at intermediate distances, offering efficient channels for the formation of ground state Cs_2 molecules after spontaneous decay. The different schemes for the formation of cold molecules will be exposed.

Temperatures of the molecular cloud as low as 20 μK and formation rates of one cold molecule per micro-second are measured. The possibility to prepare cold molecules in a well defined ro-vibrational level of the ground state through stimulated Raman photoassociation is also demonstrated.

Optical, magneto-optical and geometric forces on atom in a near-resonant monochromatic field: Analytical results

A.V.Taichenachev, A.M.Tumaikin and V.I.Yudin
Novosibirsk State University, Novosibirsk 630090, Russia
phone: (3832) 397234; fax: (3832) 397101; e-mail: llf@admin.nsu.ru

The force on atom in a spatially non-uniform light field plays a crucial role in laser cooling and trapping and in the formation of optical lattices of cold atoms. In general, such a force depends on the internal state of atom, which is anisotropic due to the resonant atom-light interaction. The case of closed optical transition, when the lower level is the ground state and the total population of levels is conserved, is of great interest, because here the light-induced anisotropy is long-lived, which allows one to accumulate information on very weak couplings. In the case of polarization gradient analytical calculations of the stationary force require knowledge of the atomic steady state in a laser field with arbitrary elliptical polarization. So far such forces was found in analytical form for transitions with $F_g \to F_e$ involving specific small values of the angular momentum ($F_g = 1/2,\ 1$) in works on laser cooling and trapping [1]. Here F_g and F_e are the total angular momenta of the ground (g) and excited (e) level.

Recently, for all closed dipole transitions $F_g \to F_e$ we have found the steady-state density matrix of atom in a compact, analytical and invariant form for a monochromatic field with arbitrary polarization, intensity and detuning [2]. This solution allows one to calculate analytically a number of dynamical characteristics of atom with the same level of generality (i.e. arbitrary angular momenta, arbitrary field polarization etc.). For example, Bezverbny, Nienhuis and one of us (AMT), using our solution, have deduced an analytical formula for the light force on atom in the rest for $F \to F$ transitions with F a half-integer [3].

In this paper we present new results, which is of especial importance for the theory of optical lattices. Namely, we find analytical expressions (i) for the resonance optical (both scattering and redistribution) forces on atom in the rest for $F \to F+1$ transitions; (ii) for magneto-optical potentials in the case of weak magnetic field, when the adiabatic conditions is fulfilled; (iii) for dark geometric (scalar and vector) potentials in the case of $F \to F$ transitions with F an integer.

1. C. Cohen-Tannoudji and J. Dalibard, J. Opt. Soc. Amer. B **6**, 2023 (1989); K. Mølmer and Ch. I. Westbrook, Laser Physics **4**, 872 (1994).
2. A. V. Taichenachev, A. M. Tumaikin, V. I. Yudin and G. Nienhuis, JETP, **81**, 224 (1995); G. Nienhuis, A. V. Taichenachev, A. M. Tumaikin, V. I. Yudin, Europhys. Lett., **44**, 20 (1998); A. V. Taichenachev, A. M. Tumaikin, V. I. Yudin, Europhys. Lett. **45**, 301 (1999).
3. A. V. Bezverbny, G. Nienhuis, A. M. Tumaikin, Opt. Comm. **148**, 151 (1998).

Seminar 4
Physics of Lasers

Tuesday, July 18, 2000

GENERAL PHYSICS OF LASERS

Chairs: Claude Rulliere (France) and I. Shcherbakov (Russia) — Session 4.1

11.00-11.30 Louis A. Lompré (Saclay, France)
Recent Progresses in Diode-Pumped YAG Lasers

11.30-12.00 U. Keller (Zurich, Switzerland)
Physics of ultrashort pulse generation

12.00-12.30 A. Apolonski, A. Poppe, G. Tempea, Ch. Spielmann, F. Krausz (Vienna, Austria) and R. Holzwarth, T.W. Haensch (Garching, Germany)
Absolute phase control of few-cycle laser pulses

12.30-13.00 P.E. Toschek (Hamburg, Germany)
Elimination of quantum noise in the beat note of a laser

13.00-14.30 Lunch

SOLID STATE LASERS

Chairs: P. Toschek (Germany) and V. Yermachenko (Russia) — Session 4.2

14.30-14.50 W. Chen, D. Boucher (Dunkerque, France), F. Tittel (Houston, USA) and P. Davies (Cambridge, UK)
High-resolution difference frequency laser spectroscopy for environmental application

14.50-15.10 N.N. Il'ichev, P.P. Pashinin (Moscow, Russia)
Narrow spectrum width cw laser operation of F_2^- colour centres in LiF

15.10-15.30 O. Parriaux (Saint-Etienne, France), A.V. Tishchenko, V.A. Sychugov (Moscow, Russia)
Design of laser grating with 100% diffraction efficiency

15.30-15.50 G.A. Bufetova, A.M. Bulkanov, I.A. Ivanov, D.A. Nikolaev, V.B. Tsvetkov, I.A. Shcherbakov (Moscow, Russia)
Simulation of operation of Nd-lasers with Cr^{4+} doped Q-switches

15.50-16.10 A.V. Kir'yanov, Yu.O. Barmenkov, V. Aboites (Leon, Mexiko), N.N. Il'ichev (Moscow, Russia)
Study of the absorption saturation mechanism in an YAG:Cr^{4+} crystal by the Z-scan technique with taking to account of the nonlinear absorption anisotropy

16.10-16.30 V.B. Tsvetkov, G.A. Bufetova, D.A. Nikolaev, I.A. Shcherbakov, Ya. Vorob'ev (Moscow, Russia)
Selfadaptive resonator for Q-switched Nd-laser starting from radiation noise

16.30-17.00 Coffee Break

NEW LASER MATERIALS

Chairs: O. Parriaux (France) and N. Il'ichev (Russia) — Session 4.3

17.00-17.25 S. Kueck, M. Henke, K. Rademaker (Hamburg, Germany)
Crystal growth and spectroscopic investigation of Yb^{2+} doped fluorides

17.25-17.50 L. Ivleva, T. Volk, P. Lykov, N. Polozkov, N. Bogodaev, V. Osiko (Moscow, Russia)
Ferroelectricity-driven optical and photorefractive properties of strontium-barium niobate crystals

17.50-18.15 E. Giorgetti, G. Margheri, F. Gelli and S. Sottini (Firenze, Italy)
Nonlinear characterization of ultrathin polymer layers by means of surface plasmon spectroscopy

18.15-18.40 I.T. Sorokina and E. Sorokin (Vienna, Austria), A. Di Lieto and M. Tonelli (Pisa, Italy), R.H. Page and K.I. Schaffers (Livermore, USA)
Laser and spectroscopic investigation of Cr^{2+}:ZnSe as an efficient tunable mid-infrared laser

18.40-19.00 G. Toci, M. Vannini, R. Salimbeni, E. Giorgetti (Firenze, Italy), M.A. Dubinskii (Burtonsville, USA)
Z-scan measurements of the nonlinear properties of crystals hosts for all-solid-state uv lasers

---

Wednesday, July 19, 2000

FIBER OPTICS

Chair: Louis A. Lompré (France) **Session 4.4**

11.00-11.30 F. Giammanco, P.Marsili, A.Ruffini (Pisa, Italy)
Amplification of harmonics generated by wave-mixing in a hollow fiber

11.30-12.00 I.A. Bufetov, M.M. Bubnov, V.B. Neustruev, V.M. Mashinsky, A.V. Shubin, V.M. Paramonov, M.V. Grekov, E.M. Dianov, A.N. Guryanov, V.F. Khopin (Moscow, Russia)
Raman gain properties of high Ge-doped and standard fibers

12.00-12.30 B.M. Dicks, F. Heine, K. Petermann, and G. Huber (Hamburg, Germany)
Characterization of a radiation-hard single-mode Yb-doped fibre amplifier at 1064nm

12.30-13.00 Michiyuki Endo (Tsukuba, Japan)
Single-sideband optical frequency comb generation using a waveguide modulator in amplified fiber loop

---

Thursday, July 20, 2000

Chair: V. Tsvetkov (Russia)
Session 4.5

11.00-11.30 A.M. Zheltikov, A.B. Fedotov, A.A. Ivanov, M.V. Alfimov, (Moscow, Russia), D. Chorvat, D. Chorvat Jr. (Bratislava, Slovak Republic), L.A. Mel'nikov, V.I. Beloglazov, Yu.S. Skibina, A.P. Tarasevitch (Saratov, Russia) and D. von der Linde (Essen, Germany)
Holey Fibers with 0.4-32 μm-Lattice-Constant Photonic Band-Gap Cladding: Fabrication, Characterization, and Nonlinear-Optical Measurements

11.30-12.00 A.V. Sokolov, D.R. Walker, D.D. Yavuz, G.Y. Yin, S.E. Harris (Stanford, USA)
Raman Generation by Phased and Antiphased Molecular States

12.00-12.30 S. Longo, D. Bruno (Bari, Italy)
Statistical models for the kinetics of quantum ensembles under laser irradiation

12.30-13.00 A. Joshi (Bombay, India)
Number–phase Wigner function for the micromaser field with injected atomic coherence

Recent progresses in diode pumped YAG lasers

Louis-André LOMPRÉ

Commissariat à l'Energie Atomique
Centre d'Etudes de SACLAY
DCC/DIR, bat. 125
91191 GIF SUR YVETTE CEDEX
phone : (33) - 1 - 69 08 68 56
fax : (33) - 1 - 69 08 79 48
e-mail : lalompre@ cea.fr

Abstract

The purpose of this paper is to present recent progresses which occurred in laser diode pumped YAG lasers working at high repetition rate typically larger than 5 kHz. Since 1985, the French atomic energy commission has chosen to focus on a selective photoionisation process called SILVA (atomic vapor laser isotope separation) for uranium enrichment. In order to be efficient, the process requires dye lasers at high power and high repetition rate. Still recently, dye laser were pumped by copper vapor laser chains.

An alternative solution to pump dye laser is now developed. It is based on high-power frequency doubled Nd:YAG modules. Performances as high as 175 W at 532 nm, 12.5 kHz and pulse duration as short as 75 ns have been obtained. The electrical/optical efficiency overpasses 5%.

In this paper we will give a description of these modules and also discuss the problems related to the doubling crystal. Furthermore we will bring more generally some informations on laser diode pumped solid state lasers.

Keywords : Laser Diode, Solid-State Lasers, Nd-YAG, doubling crystal.

Ultrafast all-solid-state lasers

Ursula Keller
Institute of Quantum Electronics, Physics Department, Swiss Federal Institute of Technology (ETH), ETH Hönggerberg, CH-8093 Zürich

Today's ultrafast all-solid-state lasers continue to demonstrate unsurpassed performances in terms of pulse duration, pulse repetition rates, average power and wavelength range: Optical pulses in the 5-femtosecond range are produced by a variety of methods. Semiconductor saturable absorber mirrors (SESAMs) were a breakthrough in 1992 and resulted in the first demonstration of self-starting and stable passive mode locking of diode-pumped solid-state lasers with an intracavity saturable absorber. Presently the frontiers in average output power of diode-pumped solid-state lasers are obtained with Nd:YAG (27 W average output power and 19 ps pulse duration), Yb:YAG (16 W and 730 fs) and Nd:glass (1.4 W, 275 fs). This basically means that μJ-level pulse energies in both the pico- and femtosecond regime are available directly from compact solid-state lasers without any cavity dumping or further pulse amplification. The frontiers in pulse repetition rate has been pushed to about 60 GHz using quasi-monolithic miniature Nd:YVO4 lasers.

"Absolute phase control of few-cycle laser pulses"

.Apolonski, A. Poppe, G. Tempea, Ch. Spielmann, F. Krausz
Photonics Institute, Vienna University of Technology, Austria
and
R. Holzwarth, T. W. Haensch
Max-Planck-Institute for Quantum Optics, Garching, Germany

Abstract:
Using a coherent nonlinear optical technique, measurement of the temporal evolution of the absolute phase of sub-6-fs wave packets has been demonstrated, permitting the generation of intense, few-cycle light with precisely reproducible electric and magnetic fields for the first time. These pulses open up the way to controlling the evolution of strong-field interactions on the time scale of the light oscillation cycle and are indispensable to reproducible attoscecond X-ray pulse generation.

Elimination of Quantum Noise in the Beat Note of a Laser

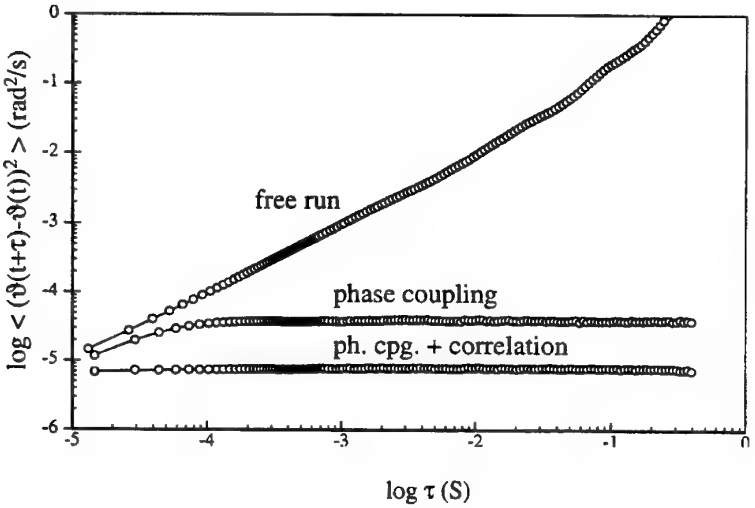
P.E. Toschek and K. Abich

Institut für Laser-Physik, Universität Hamburg
Jungiusstr. 9, D-20355 Hamburg, Germany
Tel.: 494042838 2380 -Fax: 494042838 6571 -E-mail: toschek@physnet.uni-hamburg.de

The spontaneous emissions on two coupled transitions may become correlated either by preparation of the emitter (if common upper level [1]), or by phase correlation of the emitting states (if common lower level [2]), well known from the observation of narrow "dark lines" [3]. The quantum noise on the two gain-providing lines of a corresponding bimodal laser oscillator turns correlated (CSE laser) upon the application of an rf field (ω_{rf}) that phase-correlates the upper states in the gain medium [4], such that the noise of the laser beat note at ω_{12} becomes reduced. This phenomenon has been demonstrated for $\omega_{rf} = \omega_{12}/2$ [5], and for $\omega_{rf} = \omega_{12}$ [6] with a HeNe-Zeeman laser. Phase coupling and suppression of phase diffusion have been revealed by measurements of the phase dynamics *vs.* strength of the coupling rf field and dc Zeeman splitting. In the optimum, the quantum noise of the beat note *vanishes,* within the 2% experimental uncertainty. Michelson interferometry with the light of a CSE laser permits one to achieve precision that far exceeds the limit set by quantum noise, as required, e.g., for the detection of gravitational waves.

The output of single-mode lasers of low technical noise phase-correlates an excited state with the corresponding ground state: Such light has *coherently* excited a vibrational resonance [7] and even an *electronic* resonance [8] of an individual trapped ion. The operation of quantum-logic gates is feasible on these transitions.

1. M. Schubert, I. Siemers, R. Blatt, W. Neuhauser, P.E. Toschek, Phys.Rev. A *52,* 2994 (1995)
2. I. Siemers et al., Europhys. Lett. 18, 139 (1992)
3. Th. Hansch, R. Keil, A. Schabert, Ch. Schmelzer, P.E. Toschek, Z.Physik 226, 293 (1969)
4. W. Schleich, M.O. Scully, Phys.Rev. A 37, 1261 (1988)
5. I. Steiner, P.E. Toschek, Phys.Rev.Lett. 74, 4639 (1995)
6. L. Schanz, I. Steiner, P.E. Toschek, Verhdl. DPG (IV) 30, 328, (1995)
7. B. Appasamy, Y. Stalgies, P.E. Toschek, Phys.Rev.Lett. 80, 2805 (1998)
8. R. Huesmann et al., AIP Proceedings *457,* 252 (1998)



Temporal evolution of observed phase variance of beat note

High-resolution Differenec-frequency Laser Spectroscopy for Environmental Application

Weidong Chen*, Daniel Boucher
MREID, Université du Littoral Cote d'Opale,
145 Av. Maurice Schumann, 59140 Dunkerque, France
Phone: 33 3 2865 8264
Fax: 33 3 2865 8244
* email: chen@univ-littoral.fr

Frank K. Tittel
Rice Quantum Institute, MS 366, Rice University, 6100 Main St., Houston, TX 77005, USA

Paul B. Davies
Department of Chemistry, University of Cambridge, Lensfield Road, Cambridge CB2 1EW, UK

Abstract
The increasing need for rapid, in situ characterization and quantification of atmospheric constituents has led to the development of spectroscopic monitoring techniques. Laser infrared absorption spectroscopy offers the advantage of highly selective in situ and real time measurements with detection sensitivities in the ppm to ppt range. In the mid-infrared fingerprint region from 3 to 20 μm, most molecular pollutants exhibit characteristic spectroscopic features. This permits sensitive and selective detection of numerous important atmospheric trace gases and pollutant species by laser absorption spectroscopy.

A laser difference-frequency generation (DFG) spectrometer has been developed in Dunkerque for trace gas detection [1-2]. The spectroscopic source was produced by DFG of two Ti:Sapphire lasers in a GaSe crystal. The infrared emission was continuously wavelength tunable from 8 to 19 μm by laser wavelengths tuning and z-axis orientation of the crystal under type I phase matching. The infrared generated power was ~ 0.1 μW with a spectral purity of ~1 MHz.

Recent measurements of trace amounts of various hydrocarbons, such as acetylene (nu 5 band), benzene (nu 4 band), and ethylene (nu 7 band), using high-resolution trace gas absorption spectroscopy will be presented.

References
[1] W. Chen, G. Mouret and D. Boucher: Appl. Phys. B67, 375 (1998)
[2] W. Chen, J. Burie and D. Boucher: Spectrochimica Acta A55, 2057 (1999)

Narrow spectrum width cw laser operation of *F*2- colour centres in LiF

N.N.Il'ichev, and P.P.Pashinin

General Physics Institute of RAS
Vavilov St. 38, Moscow, 117942 Russia
ilichev@kapella.gpi.ru
Phone: (095)135-03-27

Wavelength of a LiF:*F*2- laser radiation is situated in the region 1 - 1.26 μm [1]. Recently it was reported a cw operation of the laser [2]. The main problem for high power cw LiF:*F*2- laser is the problem of heat removing from area of pumping because strong thermal lens in the crystal prevents lasing [3]. In [2] rotation of LiF:*F*2- crystal was implemented to remove heat. Spectrum of laser generation was wide (100 cm-1). But for some applications it is necessary to have narrow (less than 0.1 cm-1) spectrum.

Here we report a cw LiF:*F*2- laser with narrow spectrum width. Pumping laser was cw YAG:Nd laser. Pump power was 9 W at input face of the crystal. Special scheme of spectral selection based on grating was implemented. This scheme is especially useful for lasers with low gain when internal resonator losses have to be low. It was obtained spectral width of laser radiation less than 0.1 cm-1, and frequency of radiation was stable within this spectral width during 20' of laser action.

This work was supported by European Office of Aerospace Research and Development (EOARD) SPC 99-4039, and partially by Russian Foundation for Basic Research # 98-02-17676, and #00-02-16474.

References

1. Yu.L.Gusev, A.V.Kirpichnikov, S.I.Marennikov. Kvant. Elektron., v.6, #12, 2623 (1979). [Sov. J. Quantum Electron. v.9, #12, 1554 (1979)].

2. N.N.Il'ichev, and P.P.Pashinin. Laser Physics, v.10, #1, 1 (2000).

3. Yu.L.Gusev and S.N.Konoplin. Kvant. Elektron., v.8 #6, 1343 (1981). [Sov. J. Quantum Electron. v.11, #6, 808 (1981)].

Design of laser grating with 100% diffraction efficiency

O. Parriaux(*),A.V. Tishchenko, V.A. Sychugov
Institute of General Physics, Vavilov Street 38, 117942 Moscow
(*) Jean Monnet University, F42023 Saint-Etienne

Optical diffraction gratings have now been around for more than a century. Amazingly, the grating structure has hardly changed since then, and still mostly consists of an undulated metal surface. The manufacturing technology has made a significant jump ahead since the advent of the laser, grating periods have come down, but the optogeometrical structure still remains the same. This is a quite puzzling epistemological case because nothing is worse than TM incidence on a corrugated metal surface: the incident field experiences a very strong perturbation there, and any deviation from a perfect surface smoothness is likely to excite damaging plasmon effects.

The necessity to manage high power laser beams has led to the questioning of the conventional metal grating structures, and to the systematic exploration of what dielectric gratings can bring. Dielectric gratings may still exhibit rather large scattering, but destructive absorption effects are essentially absent. Furthermore, a reflection mode of operation is more favourable with a multilayer grating than with a corrugated metal surface: first, the TE polarization can be used, and the power density can be much lower thanks to the possibility of distributing the field over a rather thick material skin[1]. It has also been shown that dielectric reflection gratings can possibly exhibit higher diffraction efficiency than their metal counterparts. This has often been found numerically on a case by case basis[2]. We are showing here how to always reach *100%* diffraction efficiency in a dielectric structure composed of a corrugated, or index modulated, thin dielectric film placed on top of a planar mirror. The condition for this is on the ratio between the grating spatial period ? relative to the wavelength ?: *?sin* ? < ? where ? is the incidence angle. Most interesting pulse compression situations, and many other grating applications, satisfy this condition. Under this condition, the sole propagating diffracted orders are the *0th* and *-1st* reflected orders.

The design we make of such structure does not result from heavy numerical computing. It simply results from applying a very simple idea based on energy conservation which can even be explained with words. In purely reflective diffractive structures, *100%* diffraction efficiency requires the cancellation of the Fresnel reflection which is usually very high. In a purely reflective structure having the *0th* and *-1st* orders only, there is no other wave available which could be used to destructively superpose with this high amplitude Fresnel reflection. This is why the diffraction efficiency of conventional metal grating falls to zero as the incidence tends to grazing incidence.

The way out of this fundamental difficulty is to define somewhere an energy accumulator in the grating region capable of restoring the accumulated energy in the form of a field of adjustable amplitude and phase. Such accumulator can be a dielectric layer on top of a mirror as illustrated in figure 1. The leakage of this energy accumulator depends on its Q factor. The leakage is in the same direction as the strong Fresnel reflection but phase-shifted by?relative to the Fresnel reflection since it results from a resonance. This provides the means to destroy the latter by means of a destructive interference. The amplitude balance leading to zero total amplitude in the Fresnel reflection direction can be adjusted by the depth of the grating which acts as a tap: when zero total amplitude is achieved, the light has nowhere else to go but to be diffracted with *100%* efficiency into the *-1st* order. The adjustment of the grating depth can be made analytically or by means of existing codes[3]. Figure 2 illustrates the frequency response of the grating with a multilayer mirror in the optogeometrical configuration of a pulse compression element. The incidence angle is 50 degrees, the grating has 1800 lines/mm, the central wavelength 800nm.

The presentation will develop further the explanation of this diffraction device, and describe the prospects which it opens for high power pulses of short duration.

References

1. A.S. Svakhin, V.A. Sychugov, A.E. Tikhomirov, «Radiation resistant optical diffraction grating for laser resonators », Quantum Electronics, ,Vol. 21, 1994, pp. 250-252.
2. M.D. Perry, R.D. Boyd, J.A. Britten, D. Decker, B.W. Shore, C. Shannon, E. Shults, L.Li, «High efficiency multilayer dielectric diffraction gratings », Optics Letters, Vol. 20, 1995, pp. 940-942.
3. IF. Salakhutdinov, V.A. Sychugov, O. Parriaux, «Highly efficient diffraction gratings for use in the Littman-Metcalf mounting », Quantum Electronics, Vol. 28, 1998, pp. 983-986.
4.

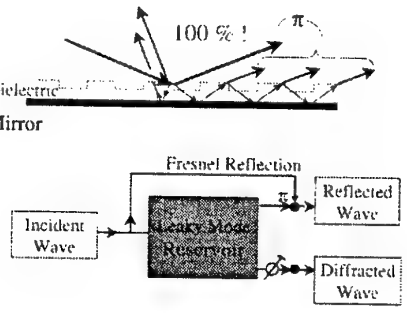


Figure 1 : Sketch of the principle of the diffraction grating with energy accumulation.

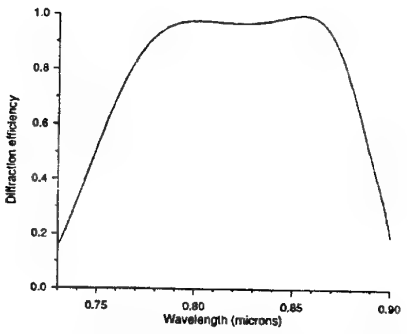


Figure 2 : Typical wavelength dependence of a pulse compression grating with dielectric mirror

Simulation of operation of Nd-lasers with Cr4+ doped Q-switches.

G.A.Bufetova*, A.M.Bulkanov**, I.A.Ivanov**, D.A.Nikolaev*, V.B.Tsvetkov*, I.A.Shcherbakov*

* - General Physics Institute, Vavilov str.,38, Moscow, Russia.
Fax: (007-095) 135-11-24, e-mail: bufetova@lsk.gpi.ru

** - Institute for Materials Research, 103460, Moscow, Russia

In this paper we report the results of computer simulation and experiments on the Q-switch bleaching during the laser operation of flashlamp pumped Nd-lasers .The goal was to investigate the laser pulse duration for different parameters of Q-switches and laser crystals.

The study of the Q-switches with initial transmissions 62%; 80%; 50% and 30% was done. The length of the Cr^{4+}:YSGG crystals used for the experiments was 5 - 7 mm. The temporal behavior of the transmission of the Q-switch shows fast bleaching and slow relaxation to the value of the initial one. It is clearly seen that maximum of the laser output takes place well before the maximum of the Q-switch bleaching to be reached. In saturation the transmission of this Q-switch is $T_{max} \approx 0.85$. With Cr^{4+}-doped Q-switch the laser emits when the transmission of the absorber is not minimal. The best contrast in bleaching one can observe for the 30% Q-switch ($T \approx 72$ % ; in saturation $T_{max} \approx 83\%$).

The Cr^{4+} doped Q-switches demonstrate slow switching accompanied by the incomplete absorption saturation during the laser pulse. The influence of this effect on the laser efficiency and the application of this property to control the operation of the pulsed passively Q-switched lasers have been simulated and compared with experimental data. Good agreement between calculated and experimental parameters enables us to use the model for the optimization of similar laser schemes.

A.V.Kir'yanov[1], Yu.O.Barmenkov[1], V.Aboites[1]

N.N.Il'ichev[2]

[1] Centro de Investigaciones en Optica A.C., Apartado Postal 948,
Leon 37000, GTO, MEXICO
Fax: (52) 47-175000, E'mail: *kiryanov@foton.cio.mx*
[2] General Physics Institute of the RAS,
Vavilov Str., 38, Moscow 117942, RUSSIA

Study of the absorption saturation mechanism in an YAG:Cr^{4+} crystal by the Z-scan technique with taking to account of the nonlinear absorption anisotropy

ABSTRACT

New features of the absorption saturation mechanism in an YAG:Cr^{4+} crystal are found by means of the Z-scan technique in steady-state at the wavelength of 1.06 μm. It is shown that the analysis of experimental Z-scans (transmittance in the open- and closed-aperture configurations) with taking into account the phenomenon of nonlinear absorption anisotropy in the YAG:Cr^{4+} crystal allows an accurate measuring of cross-section of the saturable absorption (transition $^3A_2$ - $^3T_1$ of the Cr^{4+} centers) as well as evaluation for the correspondent nonlinear part of refractive index n_2. In particular, the developed model reveals the vanishly low value of the excited state absorption of the Cr^{4+} centers in YAG crystal at the wavelength of 1.06 μm.

V.B.Tsvetkov,G.A.Bufetova, D.A.Nikolaev, I.A.Shcherbakov, Ya. Vorob'ev

Selfadaptive resonator for Q-switched Nd-laser starting from radiation noise.

General Physics Institute, 117942, Vavilov str.,38, Moscow, Russia.
Fax:(7-095)135-11-24, E-mail: tsvetkov@lsk.gpi.ru

In former times the output characteristics of Nd-lasers with adaptive loop resonator based on the intracavity four-wave mixing in the Cr-doped Q-switches were investigated [1,2]. This paper is devoted to the results of the experimental study of the ability of this type of resonator to compensate the high magnitude of optical phase distortions due to the phase conjugation. For the investigation these features we used the loop resonator (Fig.1), formed by the output coupler (OC), three high reflective mirrors (HR1, HR2, HR3) and nonlinear medium M (Cr^{4+}:GSGG crystal, also used as passive Q-switch). To create different degrees of the wave front distortions we used the nonuniformly etched glass plates GP, placed inside the cavity. During the experiment the nonlinear medium M is moved along Z direction, parallel to the optical axis of resonator (Fig.1). At two end points the crossing of the beams was outside the nonlinear medium and the resonator operated as a common one, but in the medium point the crossing of the beams was inside the Q-switch and four-wave mixing took place.

We have studied experimentally the changes in lasing efficiency as a function of the position Z of the nonlinear medium, the value of the phase distortions and the position of the plates GP (pos. A and B in Fig.1). The output characteristics for different value of the initial transmission of the passive Q-switch were also investigated.

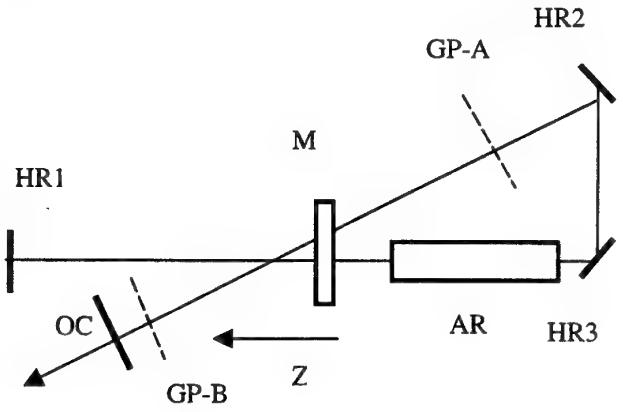


Fig.1. Optical diagram of the experimental set-up.

The results of the experiments demonstrate, that adaptive loop resonator efficiently compensates all the phase distortions of the intracavity beam and lasing efficiency of Nd-laser with this type of the cavity was considerably higher, than the efficiency of the common laser with the same resonator parameters.

This research was performed under INTAS grant 97-2112.

References.

1. G.A.Bufetova, I.V.Klimov, D.A.Nikolaev, I.A.Shcherbakov, V.B.Tsvetkov. Solid-state laser with intracavity four- wave mixing occurred in Cr^{4+}:YSGG, OSA Proceeding on Advanced Solid-State Lasers, v.24, p.438, 1995
2. G.A.Bufetova, D.A.Nikolaev, I.A.Shcherbakov, V.B.Tsvetkov. Dynamic gratings in Cr^{4+}:GSGG saturable absorber. Laser physics, v.8, No.1, p.227, 1998

Crystal growth and spectroscopic investigation of Yb2+doped fluorides

S. Kück, M. Henke, K. Rademaker
Universität Hamburg, Institut für Laser-Physik
Jungiusstraße 9a, 20355 Hamburg, Germany
phone: ++49/40/42838-5243, fax: ++49/40/42838-6281
e-mail: kueck@physnet.uni-hamburg.de

Lasers in the UV and visible spectral range can be used in a wide field of applications such as biology, medicine, display technology, data storage, printing industry, scientific research, and entertainment. One possible way to realise laser oscillation in this spectral range is the exploitation of the parity allowed (and thus electric-dipole allowed) 4f - 5d transitions of divalent and trivalent rare earth ions, such as e.g. Ce3+ [1]. In this presentation, we report on the preparation and spectroscopic investigation of the Yb2+ ion. Yb2+ has a completely filled 4f shell, therefore there are no innershell 4f transitions. The observed transitions are thus assigned to 4f-5d transitions. First investigations were performed in alkaline earth halides and alkali halides and recently in fluorides and oxides [2]. Here, preparational aspects and laser relevant spectroscopic data on Yb2+-doped MgF2, KMgF3, LiCaAlF6 (LiCAF) and LiSrAlF6 (LiSAF) will be presented.

All crystals were grown from stoichiometric melts by the Czochralski method using RF-heating, carbon crucibles and automatic diameter control. Single crystals were grown in good optical quality and diameters up to 14 mm. The starting materials were pre-melted under HF atmosphere to avoid traces of oxygen and water. LiSAF, LiCAF and MgF2 contain a suitable divalent cation site, so a reducing atmosphere (N2 + 5% H2) during the growth was sufficient to stabilise the divalent state of Yb. In KMgF3 the Yb2+-ion occupies the monovalent K+ site. Therefore charge compensation was utilised by codoping with lithium.

All materials exhibit broadband emission in the short wavelength region due to a 5d-4f transition. The peak emission wavelength and bandwidths at room temperature are in particular: 485nm and 4510cm-1 for Yb2+:MgF2, 405nm and 3890cm-1 for Yb2+:KMgF3, 393nm and 3260cm-1 for Yb2+:LiCAF, 440nm and 5180cm-1 for Yb2+:LiSAF, respectively. The emission can be excited in a variety of bands resulting from the 4f135d configuration. The room temperature decay time of the Yb2+ emission is 52 µs in MgF2, 80 µs in KMgF3 [2], 5.4 µs in LiCAF and 9.9 µs in LiSAF, respectively.

An interpretation of the energy level scheme of the Yb2+ 4f135d configuration will be given as well as a detailed analysis of the temperature dependence of excitation, emission and decay times.

[1] A.J. Bayramian, C.D. Marshall, J.H. Wu, J.A. Speth, S.A. Payne, G.J. Quarles, V.K. Castillo, J. Lumin. 69 (1996) 85

[2] S. Lizzo: Luminescence of Yb2+, Eu2+ and Cu+ in solids. PhD thesis, Universiteit Utrecht 1995

FERROELECTRICITY-DRIVEN OPTICAL AND PHOTOREFRACTIVE PROPERTIES OF STRONTIUM-BARIUM NIOBATE CRYSTALS.

L. Ivleva, T. Volk*, P. Lykov, N. Polozkov, N. Bogodaev, V. Osiko

Institute for General Physics of the Russian Academy of Science, Moscow 117942
ivleva@ran.gpi.ru
* Institute of Crystallography of the Russian Academy of Science, Moscow 117333

Photorefractive properties of $Sr_xBa_{1-x}Nb_2O_6$ (SBN) crystals are dependent on ferroelectric phenomena, which is exemplified by the field fixing of holograms [1] and field-controlled two-beam coupling gain Γ [2]. Ferroelectric properties of SBN are particularly governed by rare-earth (RE) doping [2,3]. Our aim is to investigate the action of non-photorefractive RE co-dopants on SBN crystals doped with photorefractive impurities in order to detect specific optical effects related to ferroelectric origin of the crystals. Here we report on effects of La doping on Γ in SBN:Ce crystals which show very high values of Γ [4]. Gratings were recorded by a He-Ne laser. Parameters of SBN:0.1wt.%Ce:1wt.%La in comparison with SBN:0.1wt.%Ce are shown in the Table. Co-doping of SBN:Ce with La does not affect optical absorption spectra and therefore the density of carrier traps N_{eff} , whereas ferroelectric properties are strongly modified. The phase transition temperature T_c is drastically lowered which results in an essential increase of electrooptic coefficients and a decrease of the coercive field E_c . The ferroelectric P-E loops are improved, since their shape is not more affected by multiple switching under field pulses E_{ext}. We studied the effects of E_{ext}. applied after recording on the behavior of Γ. A dependence of Γ on E_{ext} follows from the relations

$$\Gamma = (n^3/\lambda)(E_{sc}\, r_{eff}/m\cos\theta)\ ,\quad r_{13} = 2g_{13}P_s\varepsilon_{33}\varepsilon_0,\quad r_{33} = 2g_{33}P_s\varepsilon_{33}\varepsilon_0$$

(where g_{ij} are coefficients of the Kerr effect in the paraelectric phase). Unlike in SBN:Ce, the dependence $\Gamma(E_{ext})$ in SBN:Ce:La shows a hysteresis which repeats the shape of P-E loops. A reversal of the sign of Γ following the spontaneous polarization P_s reversal means a change in the direction of the energy transfer between the recording beams. The value of Γ shows no degradation after multiple switching cycles. The sign and the value of Γ are stored after switch-off E_{ext} up to applying the next pulse field switching P_s. Therefore, properties of SBN:Ce:La are relevant for creating a bistable reproducible optical element with a high Γ controlled by relatively low external fields.

In spite of a noticeably higher electrooptic coefficients, the value of Γ in SBN:Ce:La is lower than in SBN:Ce. The main reason is that La enhances a hole component of photoconductivity, as seen from a decrease of the electron-hole competition factor ζ.

Crystal	T_c,°C	ε_{33} (20°C)	r_{33}, pm/V	Γ_{max}, cm^{-1}	N_{eff}, cm^{-3}	ζ
SBN:Ce:La	43	8500	1000	20	$2.6\ 10^{17}$	0.29
SBN:Ce	80	850	255	27	$2.5\ 10^{17}$	0.56

1.F.Micheron, C.Mayeux, J.C. Trotier, Appl.Opt., **12**, 784, (1974)
2.T.Volk, Th.Woike, U.Doerfler, R.Pankrath, L.Ivleva, Ferroelectrics, **203**, 457 (1997)
3.T.Volk, V. Salobutin, L. Ivleva, N.Polozkov, in press: Sov.Physics:Solid State, (2000)
4. R.R.Neurgaonkar, W.K.Cory, M.D.Ewbank,W.F.Hall, Opt.Eng., **26**, 392, (1987)

SUBMITTED TO: PHYSICS OF LASERS

NONLINEAR CHARACTERIZATION OF ULTRATHIN POLYMER LAYERS BY MEANS OF SURFACE PLASMON SPECTROSCOPY E. Giorgetti, G. Margheri, F. Gelli and S. Sottini
Istituto di Ricerca sulle Onde Elettromagnetiche - CNR, Via Panciatichi 64, 50127 Firenze, Italy

The challenging requirements of future all-optical signal processors based on guided-wave optics have stimulated the investigation and characterization of nonlinear materials such as polydiacetylenes (PDAs). These polymers have been extensively studied, both for their unique π-electronic properties, that produce large optical nonlinearities with subpicosecond response times, and for their potential low cost. Among PDAs, the polycarbazolyldiacetylenes (polyDCHDs), that are characterized by the highly polarizable carbazolyl rings attached to the backbone through methylene groups, are expected to exhibit large off-resonance values of $\chi^{(3)}$. The $\chi^{(3)}$ of ultrathin films (10-50 nm) of POLY-DCHD-HS deposited on silver was measured at 1064 nm and with picosecond pulses using Surface Plasmon Spectroscopy (SPS): all samples exhibited a negative and real $\chi^{(3)}$ of the order of 10^{-17} m^2/V^2. The potentialities of SPS will be discussed both as a material characterization procedure and as a means of developing future devices.

Contact author: Emilia Giorgetti
Institution: Istituto di Ricerca sulle Onde Elettromagnetiche - CNR
Street/PO Box: Via Panciatichi 64
zip/City: 50127, Firenze
Country: Italy
Phone: 0039-055-4235223
Fax: 0039-055-410893
E-mail: Sottini@iroe.fi.cnr.it

Laser and spectroscopic investigation of Cr^{2+}:ZnSe as an efficient tunable mid-infrared laser.

Irina T. Sorokina and Evgeni Sorokin
Photonics Institute, TU Wien,
Gusshausstr. 27/387, A-1040 Wien, Austria
E-mail: sorokina@tuwien.ac.at
Tel: +43 1 58801-38721, Fax: +43 1 58801-38799

Alberto Di Lieto and Mauro Tonelli
Dipartimento di Fisica, University of Pisa, Via Buonarotti 2, 56100-Pisa-Italy

Ralph H. Page and Kathleen I. Schaffers
Lawrence Livermore National Laboratory, Mail Code L-441,
P.O. Box 808, Livermore, CA 94550

There is an increased interest in Cr^{2+} doped ZnSe crystals as active media for tunable continuous-wave [1-3] as well as mode-locked lasers [4], operating in the interesting for many applications water window wavelength range around 2.4-2.5 microns. In our recent work we demonstrated more than 0.5 W of cw output power with the slope efficiency of 63 %, tunable over more than 600 nm, pumping with 1.5 W at 1.75 μm [2]. Very recently 1 W of cw output power was achieved [3]. Feasibility of diode-pumping makes this material especially attractive. However, many researchers reported the problem of high level of passive losses at laser wavelength in highly concentrated Cr:ZnSe samples, which are necessary for diode-pumping.

In this paper using spectroscopic as well as laser study we carry out a comparative analysis of the Cr:ZnSe single crystals and polycrystalline Cr:ZnSe, the latter material being attractive for its low cost and availability. We found that polycrystalline material is distinguished by the higher concentration of OH complexes. We also found that intrinsic losses are actually higher than those usually measured by inverse slope efficiency method and are limited by the absorption within the $^5T_2$ state of Cr^{2+} due to Jahn-Teller effect. This knowledge allows predicting the accessible in this material threshold as well as tunability range. Finally we present the results of theoretical analysis of the observed in this laser coupled-cavity passive Q-switching regime.

References:

1. 1.. G. J. Wagner, T. J. Carrig, R. H. Page, K. I. Schaffers, J. Ndap, X. Ma, and A. Burger, Opt. Lett., **24**, 19-21 (1999).
2. I. Sorokina, E. Sorokin, A. DiLieto, M. Tonelli, R. Page, K. Schaffers, paper MC6 in ASSL'2000.
3. N.V. Kuleshov, A. V. Podlipensky *et al,* Postdeadline paper in ASSL'2000.
4. T. J. Carrig, . G. J. Wagner, A. Sennaroglu, J. Y. Jeong, C. R. Pollock, Opt. Lett., **25**, 168-170 (2000).

SUBMITTED TO: PHYSICS OF LASERS

Z-SCAN MEASUREMENTS OF THE NONLINEAR PROPERTIES OF CRYSTALS HOSTS FOR ALL-SOLID-STATE UV LASERS

G. Toci [1], M. Vannini [1], R. Salimbeni [1], E. Giorgetti [2] and M. A. Dubinskii [3]

[1] *Istituto di Elettronica Quantistica – CNR,Firenze, Italy*

[2] *Istituto di Ricerca sulle Onde Elettromagnetiche - CNR, Firenze, Italy*

[3] *Science and Engineering services, Inc., Burtonsville, MD, USA*

Host crystals such as LiCaF, $LiBaF_3$ and $LiLuF_4$ are promising candidates for the development of all-solid-state lasers in the UV range, by proper doping with Ce^{3+} ions. For this purpose, the knowledge of their nonlinear behaviour is very important. The z-scan technique was adopted to measure the $\chi^{(3)}$ of these materials in the picosecond time scale. The experiments were performed by using the second harmonic of an actively/passively mode-locked Nd:YAG laser (532 nm, 27 ps FWHM and 10 Hz repetition rate) and a saffire sample as a reference. In all cases, the resulting $\chi^{(3)}$ values were positive and real; in particular, the nonlinear refractive index values, that ranged between 0.7 10^{-16} (LiCaF) and 2.7 10^{-16} ($LiBaF_3$) cm^2/W were always smaller than saffire at the same wavelength.

Contact author: Guido Toci
Institution: Istituto di Elettronica Quantistica - CNR
Street/PO Box: Via Panciatichi 56/30
zip/City: 50127, Firenze
Country: Italy
Phone: 0039-055-416128
Fax: 0039-055-414612
E-mail: Toci@ieq.fi.cnr.it

AMPLIFICATION OF HARMONICS GENERATED BY WAVE-MIXING IN A HOLLOW FIBER

F. Giammanco, P.Marsili, A.Ruffini

Dipartimento di Fisica e Unitá INFM – University of Pisa
via F.Buonarroti 2, 56127 Pisa, Italy
tel:0039-050-844505- fax:0039-050-844333
E-mail:GIAMMA@difi.unipi.it

We have investigated in detail the harmonic spectrum produced in different gases by mixing of the fundamental and the second harmonic of a 100-mJ 35-ps Nd-YAG laser. Even and odd harmonics of fundamental wavelength are generated by wave-mixing. In addition, the wave-mixing scheme enhances the conversion efficiency by at least two orders of magnitudes compared with the single frequency excitation. We observed that the conversion efficiency is quite insensitive to the phase mismatch due to the refractive index of electrons produced by multiphoton ionization within a wide range of gas density variation. By a different configuration of the interaction zone, we observed a noticeable enhancement of harmonic conversion in both gases as the interaction length increases[1-3]. In this work, we investigate the enhancement of the conversion efficiency when both laser beams are guided by a hollow fiber filled by gas versus the experimental parameters. We show that the numerical solution of the propagation equation, which includes electron-ion scattering as the basic mechanism of harmonic generation [4], gives a good description of the experimental results.

1) F. Giammanco,P.Ceccherini,et al., Laser Physics **7**, pp.22-31, 1997
2) F. Giammanco and P.Ceccherini, Laser Physics **8**, pp.1-6, 1998
3)F.Giammanco, P.Ceccherini, T.Di Palma-"Two-color Multiphoton Ionization and Harmonic Generation"-in Proc. of Italian-Russian Symposium on Ultrafast Optical Physics-"Tribute to N.I.Koroteev"-G.Ferrante,M.Vaselli and A.Zheltikov eds.,Intellekt-Tsentr, pp.23-46, Moscow,2000
4) V.P.Silin, Quantum Electronics, 29,pp.11-18 (1999)

Raman gain properties

of high Ge-doped and standard fibers

I.A.Bufetov*, M.M.Bubnov*, V.B.Neustruev*, V.M.Mashinsky*, A.V.Shubin*,

V.M.Paramonov*, M.V.Grekov*, A.N.Guryanov**, V.F. Khopin**, B.M.Dianov*.

*) Fiber Optics Research Center at the General Physics Institute of the Russian Academy of Sciences, 38 Vavilov Street, 117756, Moscow, Russia

**) Institute of Chemistry of High-Purity Substances of the Russian Academy of Sciences, 49 Tropinin Street, 603600, Nizhny Novgorod, Russia

Abstract - A Raman gain properties of a special high Ge-doped fiber, commercial NZ DSF and large effective area fiber have been investigated. The fibers mentioned have been studied as active media of Raman fiber amplifiers at the wavelengths of 1.5 μm and 1.3 μm. The highest value of fiber Raman gain coefficient is determined for the high Ge-doped fiber to be 23.3 dB/(km.W). As a pump source Raman fiber lasers operating at the wavelengths of 1.407 and 1.229 gm have been used.

The recent emergence of Wavelength Division Multiplexing technology has led to a tremendous increase in the transmission capacity of optical fiber communication systems up to a terabit per second [i]. The further increase in the transmission capacity can be achieved by expanding the spectral region for WDM transmission to the shorter wavelength bands. Raman fiber amplifiers (RFAs) are very attractive units for telecommunication systems because they can operate practically at any wavelength in the low loss window of optical fibers. For this reason the choice of optimal fiber types for RFAs operating in different parts of wavelength spectrum is of much current interest. In this paper we report the measured Raman gain characteristics of standard and special fibers at two different wavelengths.

The high GeO_2-doped fibers are attractive medium for the discrete fiber Raman amplifiers. These fibers enable to minimize the pump power and the length of the fiber. On the other hand, the standard communication fibers are apparent active medium for distributed Raman amplifiers. We have investigated the gain properties of both types of the fibers.

Characterization of a radiation-hard single-mode Yb-doped fibre amplifier at 1064nm

B.-M. Dicks[1], F. Heine[2], K. Petermann[1], and G. Huber[1]

[1] *Institut für Laser-Physik, Universität Hamburg, Jungiusstraße 9a, D-20355 Hamburg, Germany (phone: +4940-42838 2634, fax: +4940-42838 6281, e-mail: dicks@physnet.uni-hamburg.de)*

[2] *Bosch Telecom GmbH, Gerberstraße 33, D-71522 Backnang, Germany*

Summary

For coherent optical space communications, lasers supplying several Watts of output power in a single longitudinal and transverse mode are needed. Available phase modulators in the GHz range show insertion losses of typically 3dB and damage thresholds as low as 50mW. Therefore master oscillator-power amplifier schemes have to be used. Because in satellites radiation shielding and electrical power are limited, the laser system should exhibit a certain degree of radiation hardness and a high electrical-to-optical efficiency. From these conditions, the use of diode-pumped solid-state lasers is attractive. Especially Nd- and Yb-doped systems can be designed to be highly efficient. Because single-mode lasing is achieved much easier in Neodymium-lasers, this is the material of choice for the master oscillator.

In our experiments, a commercially available Nd:YAG non-planar ring laser was used to generate the single-mode input signal for the amplifier. This laser material has been demonstrated to possess sufficient radiation hardness, especially when codoped with Cr^{3+} [1]. For the amplifier, single-mode glass fibers offer TEM_{00} output and the opportunity to end up with a minaturized monolithic setup [2].

Under Ti:Al_2O_3 pumping into the single-mode core, we compared several samples of Nd- and Yb-doped glass fibers before and after γ-irradiation. A special Yb-doped fibre was selected, which also could be efficiently diode-pumped (see below). This fibre gave an output of 1.0W with 1.75W of pump and 50mW of signal input (unirradiated, 59% optical-to-optical efficiency). Immediately after γ-irradiation, the output dropped only by 30%. Comparative absorption spectra of the unirradiated and γ-irradiated preforms were measured.

Under diode pumping, an output power of 2.2W at 1064nm was achieved with 3.9W of pump and 50mW of signal input (56% optical-to-optical efficiency). The M^2 at full output was measured to be 1.08±0.15 and the line width was determined to be less than 21MHz (resolution limit of the scanning Fabry-Perot). The extracted output did not increase significantly with signal input powers exceeding 5mW. The ASE level (blocked by an interference filter) was determined for varying pump and signal powers and was typically below 5% of the output at 1064nm.

References

[1] T.S. Rose, M.S. Hopkins, and R.A. Fields, IEEE J. Quant. El. **31**, no. 9, 1593 (1995)

[2] L. Goldberg, J.P. Koplow, and D.A.V. Kliner, Opt. Lett. **24**, no. 10, 673 (1999)

Single-sideband optical frequency comb generation using a waveguide modulator in amplifyied fiber loop

Michiyuki Endo

Electrotechnical Laboratory, 1-1-4 Umezono, Tsukuba 305-8568, Japan
Phone: +81-298-61-5639, Fax: +81-298-61-5640, E-mail: mendo@etl.go.jp

The precise measurement of difference frequencies between two lasers in a terahertz region is a basic technique for optical frequency standards and for many other applications, such as dense WDM communication systems. Optical frequency difference measurements based on the beat signal between two lasers become quite difficult when the frequency difference exceeds the detector bandwidth. An optical frequency comb (OFC) generator with an electro-optic phase modulator inside a Fabry-Perot cavity can overcome this problem [1]. In conventional OFC generation, modulation sidebands appears on both sides of the carrier, which is a disadvantage for the efficient use of frequency bandwidth. The limit of the frequency difference measurement with this scheme depends on the power degradation in the sidebands.

A novel technique is proposed to generate single-sideband optical frequency comb (SSB-OFC) in a dual-electrode waveguide Mach-Zehnder modulator (D-MZM) placed in an optical fiber recirculating loop containing an Er doped fiber amplifier. This SSB-OFC enables the efficient use of the frequency bandwidth. The fiber amplifier is used in the loop to compensate for the losses. The OFC generator creates a large number of sidebands, which can be applied for frequency markers. At the first step, we did experiment for SSB generations using the D-MZM. A 2-18 GHz synthesizer was used to generate the modulation signal. An RF power of about 23 dBm was applied to the each electrodes via a 3 dB coupler after being amplified by a power amplifier. A phase shifter provides the $\pi/2$ phase difference in the RF signals. The output power of the reference laser is -3 dBm at wavelength 1550 nm, and the optical SSB is clearly visible. OFC generation is achieved by successive phase modulation of the laser reference line in the loop. The resulting OFC has absolute frequencies determined by reference laser and a spacing determined by the RF frequency applied to the modulator. To generate the maximum number of combs, the modulation frequency should be a harmonic of the round-trip frequency of the fiber loop. With a reference laser wavelength of 1528 nm, the SSB-OFC with a frequency span of 1.2 THz (68 combs) was generated.

Although the experimental frequency used was 18 GHz, it is possible to use a higher frequency. In actual condition, there is a limit on the span of the SSB-OFC generation due to material dispersion in the electro-optic crystal and amplified spontaneous emission noise in the fiber amplifier. It is necessary to adjust loop circulating delay under closed control to satisfy the loop condition. Thus, a portion of the loop output is detected by a photodiode to generate an error signal for locking.

[1] M. Kourogi, K. Nakagawa, M. Ohtsu, IEEE J. QE 29, 2693 (1993)

Holey Fibers with 0.4–32-μm-Lattice-Constant Photonic Band-Gap Cladding: Fabrication, Characterization, and Nonlinear-Optical Measurements

A.B. Fedotov,[a] A.M. Zheltikov,[a] A.A. Ivanov,[b] M.V. Alfimov,[b] D. Chorvat,[c] D. Chorvat Jr.,[c] L.A. Mel'nikov,[d] V.I. Beloglazov,[e] Yu.S. Skibina,[e] A.P. Tarasevitch,[f] and D. von der Linde[f]

[a] **International Laser Center, Faculty of Physics, Moscow State University, Moscow, Russia**

[b] **Center of Photochemistry, Russian Academy of Sciences, Moscow, Russia**

[c] **International Laser Center, Bratislava, Slovak Republic**

[d] **Saratov State University, Saratov, Russia**

[e] **Institute of Technology and Processing of Glass Structures, Russ. Acad. Sci., Saratov, Russia**

[f] **Institut für Laser- und Plasmaphysik, Universität Essen, Essen, Germany**

Optical fibers with a photonic-crystal cladding (or holey fibers) [1] is a new promising type of waveguides where electromagnetic waves are guided along a defect in a two-dimensional photonic band-gap structure consisting of a periodic array of air holes in a silica fiber. The missing hole in such a structure forms a defect in a two-dimensional photonic-crystal lattice, while the remaining part of the structure serves as a photonic crystal cladding, allowing robust low-loss single-mode waveguiding within a broad frequency range. Such fibers open a way to extend many ideas of the physics of photonic band-gap (PBG) structures to the optical range. At the same time, remarkable waveguiding properties of such fibers make it possible to form single waveguide modes with effective areas considerably exceeding those typical of conventional fibers [1].

In this paper, we summarize the results of our studies devoted to the investigation of the structure and optical properties of holey fibers with the lattice constant of the PBG cladding ranging from 0.4 to 32 μm (Fig. 1) and demonstrate the spectral broadening of 150-fs pulses of a Ti:sapphire laser propagating through such holey fibers (Fig. 2). These studies demonstrate that the use of holey fibers allows the efficiency of spectral broadening of ultrashort pulses and, generally, nonlinear-optical interactions [2] to be considerably increased within a broad spectral range.

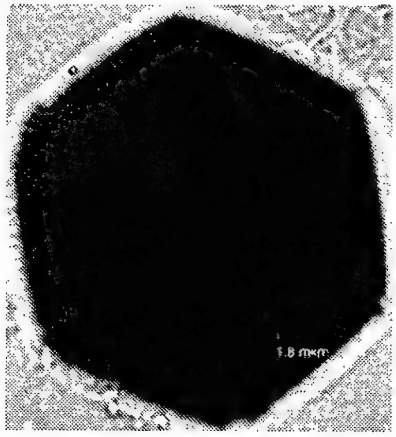


Fig. 1 A microscope image of the cut of a holey fiber.

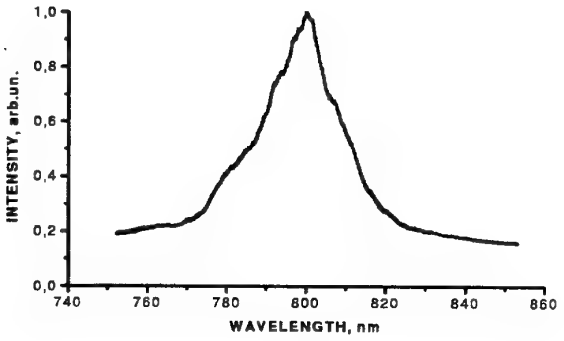


Fig. 2. Spectral broadening of a 150-fs Ti: sapphire laser pulse at the output of a holey fiber with a 1.7-μm pitch of the PBG cladding.

This study was supported in part by the President of Russian Federation Grant no. 00-15-99304, INTAS project no. 97-0369, and the Russian Foundation for Basic Research project no. 00-02-17567. Transmission spectra were measured with the equipment of the Optical Spectroscopy Division of the Collective Use Center, Center of Photochemistry, RAS.

1. J.C. Knight, T.A. Birks, P.St.J. Russell, and D.M. Atkin, *Opt. Lett.*, **21**, 1547 (1996); J.C. Knight, T.A. Birks, R.F. Cregan, P.St.J. Russell, and J.-P. de Sandro, *Opt. Mater.*, **11**, 143 (1999).

2. A.B. Fedotov, A.M. Zheltikov, L.A. Mel'nikov, A.P. Tarasevitch, and D. von der Linde, *JETP Lett.* **71**, no. 7 (2000).

Raman Generation by Phased and Antiphased Molecular States

A. V. Sokolov, D. R. Walker, D. D. Yavuz, G. Y. Yin, and S. E. Harris

Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305

E-mail: sokol@leland.Stanford.edu, Phone: (650) 725-2260, Fax: (650) 725-4115

We propose and analyze a technique for producing subfemtosecond pulses of radiation. The essence of this technique is the use of a Raman transition with a sufficiently large coherence that the generation length and phase-slip length are of the same order. This coherence is established by driving the molecular transition with two single-mode laser fields, slightly detuned from the Raman resonance so as to excite a single molecular eigenstate. Molecular motion, either in phase with the driving force (Raman detuning below resonance) or antiphased (detuning above resonance), in turn modulates the driving laser frequencies, causing the collinear generation of a very broad FM-like spectrum.

In our experiment we use molecular deuterium to demonstrate collinear generation of mutually coherent equidistant sidebands, covering 50,000 cm^{-1} of spectral bandwidth and ranging in wavelength from 2.94 μm to 195 nm. We show that, in agreement with theory, generation maximizes at a finite detuning on either side of the Raman resonance. We demonstrate a good beam quality and a perfect relative coherence of anti-Stokes Raman sidebands with respect to the driving fields. This mutual coherence among the sidebands will allow us to recombine them and use spectral modification techniques to synthesize any specified subfemtosecond time structures in a target cell.

REFERENCES: S. E. Harris and A. V. Sokolov, Phys. Rev. A **55**, R4019 (1997); S. E. Harris and A. V. Sokolov, Phys. Rev. Lett. **81**, 2894 (1998); A. V. Sokolov, D. D. Yavuz, and S. E. Harris, Opt. Lett. **24**, 557 (1999); A. V. Sokolov, Opt. Lett. **24**, 1248 (1999); D. D. Yavuz, A. V. Sokolov, and S. E. Harris, Phys. Rev. Lett. **84**, 75 (2000); A. V. Sokolov, D. R. Walker, D. D. Yavuz, G. Y. Yin, and S. E. Harris, Phys. Rev. Lett. (2000) (accepted for publication); A. V. Sokolov, D. D. Yavuz, D. R. Walker, G. Y. Yin, and S. E. Harris, "Highly Coherent Anti-Stokes Raman Generation," (to be published).

Statistical models for the kinetics of quantum ensembles under laser irradiation

S.Longo, D.Bruno

Dipartimento di Chimica dell'Universita' and Centro di Studio per la Chimica dei Plasmi del CNR, Via Orabona 4, 70126 Bari, Italy
s.longo@area.ba.cnr.it, d.bruno@area.ba.cnr.it

• The description of the state and the time evolution of a statistical ensemble of quantum systems under laser irradiation given by the density matrix[1] [2] is very general. A better description is given by the distribution function f(r), where r is set of parameters (e.g. c-numbers) necessary to identify the state of a single system. For an ensemble of 2-level systems (TLS) one can consider a probability distribution over the Riemann sphere of states S, $f(\vartheta,\varphi)$.

• The time evolution of $f(\vartheta,\varphi,t)$ can be obtained by solving a Master equation[3] [4] analogous to the Redfield equation[5] , which has a similar structure but applies to the density matrix. The equation can be solved easily by using the Green Function Monte Carlo method: the steady state result for an ensemble of TLS under a classical electric field is typically a uniform distribution over S. Such a result describes the loss of coherence but fails to explain any measurement performed on the ensemble: generic decoherence and measurement are equivalent for the density matrix but not equivalent in terms of $f(\vartheta,\varphi)$.

• A class of collective, mean field models can also be proposed by analogy to collective models of ideal plasmas, based on self-consistent volume forces. In such models a contribution to the single particle hamiltonian is a given functional W of $f(\vartheta,\varphi)$[6]. W can describe a contribution to the total energy due to the interaction of any single system with the mean field due to the other systems.

• The approach can be extended easily to multi-level systems, or equivalently to spin states $S>1/2$, by using the Majorana representation[7] for the single system state: this leads to consider N Riemann spheres and the related distribution function over S^N, for $N+1$ level systems, $S=N/2$ spin states.

Work supported by MURST under project 9802276194_004 (Plasma interaction with nano and pico second lasers)

---

[1] Chemical and Biochemical applications of Lasers, ed. C. Bradley Moore, Academic Press (1974)
[2] M.Nakano, K.Yamaguchi, Chem.Phys.Lett. **295** (1998) 317, 328
[3] N.G.Van Kampen, *Stochastic Processes in Physics and Chemistry*, Elsevier 1981
[4] S. Longo, D. Bruno, M. Capitelli, P. Minelli, Chem.Phys.Lett. **316** (2000) 311
[5] A.G.Redfield, IBM J.Res.Develop. 1 (1957) 19
[6] S.Longo, Physics Letters A in press (2000)
[7] E. Majorana, Nuovo Cimento 9 (1932) 43

NUMBER-PHASE WIGNER FUNCTION FOR THE MICROMASER FIELD WITH INJECTED ATOMIC COHERENCE

A. Joshi *

Laser and Plasma Technology Division, BARC, Trombay,
Bombay 400 085, India

The study of micromaser has been a topic of great interest for more than a decade. Much effort has been focused on generating and detecting micromaser field with sub-Poissonian statistics, as well as investigating radiation 'trapping states' and possibility of generating Fock state field. Usually two-level atoms enter the maser cavity successively in their excited ($|e\rangle$) state. The cavity is tuned with atomic transition frequency and each excited atom as it enters, sees the field build up by its predecessors together wi th the blackbody contribution. In due course cavity field builds up, however, there is no mean phase for the steady state field. If the phased atoms, i.e., atoms in the coherent superposition of their two states are introduced in the micromaser cavity, then as a result of atoms driving the cavity, the field acquires some definite phase. In this work we investigate the phase distribution along with the number distribution of the cavity field which has been resulted due to injected coherence by the phased ato ms. The question of phased atom pumping the micromaser has been addressed by other groups also but under certain approximations. The problem of phased atom input to the micromaser cavity is very complicated one, as after each input of atom, the entire den sity matrix, i.e., diagonal as well as off diagonal elements get coupled to each other. With the next input atom more number of off-diagonal elements of field density are coupled and the problem becomes very complicated one. In order to simplify our probl em we make a typical choice of the interaction time (t_{int}) such that $t_{int} < t_{revival}$ and the joint atom-field wave function factorizes into an atomic and field part throughout the interaction so that each system independetly remain in the pur e state.

We have explored the evolution of number and phase distribution of the micromaser field with phased atom input using the number-phase Wigner function, $W_{\rm NP}(n,\theta)$. This function is a natural choice for studying this problem since the marginal of $W_{\rm NP}(n,\theta)$ representing photon number is *discrete*. The other marginal of $W_{\rm NP}(n,\theta)$ is a continous variable *phase*. We can study both number as well as phase distribuitin simultaneoulsy for a micromaser in steady state under various choice of parameters, e.g., t_{int}, amplitudes and phase of the phased atoms. We will be presenting some typical and interesting results from our this study.

References

1. A .Joshi et al, J. Mod. Opt. **43**, 971 (1996) and references therein.
2. J. A Vaccaro, *Phys. Rev. A* **52** , 3474 (1995).
3. J. A. Vaccaro, A. Joshi, *Phys. Lett. A* **243**, 13 (1998).
4. A. Joshi and J. A. Vaccaro in NATO Proceedings (1999).

*email: ajoshi@apsara.barc.ernet.in
Physics of Laser

Seminar 5
Laser Methods in Medicine and Biology

Monday, July 17, 2000

Chairs: S. Gonchukov (Russia) and G. Müller (Germany) — Session 5.1

11.00-11.30 H. Weber, B. Zuger, B. Ott, Th. Schaffner, P. Mainil-Varlet, M. Frenz (Bern, Switzerland)
Dye-enhanced articular cartilage soldering

11.30-12.00 R. Steiner, D. Russ, A. Kienle (Ulm, Germany)
Optimization of laser epilation by simulation of the thermal laser effect

12.00-12.30 N. Tankovich (San Diego, USA)
Nonselective laser thermolysis for the blood vessels ablation

12.30-13.00 E .Sobol, A. Omelchenko, A. Sviridov, V. Bagratashvili, N. Vorobieva (Troitsk, Russia), Yu. Ovchinnikov, V. Svistushkin, V. Baskov (Moscow, Russia)
Novel laser applications for reshaping and treatment of deformed and diseased cartilage

13.00-14.00 Lunch

Chairs: J. Lademann (Germany) and H. Weber (Switzerland) — Session 5.2

14.00-14.35 D. Goujon, M. Zellweger, A. Radu, N. Lange, P. Monnier, G. Wagnieres, Hubert van den Bergh (Lausanne, Switzerland)
Fluorescence endoscopy for the detection of early stage cancer in the lung and esophagus

14.35-15.05 E. Stranadko, U. Koraboyev, M. Riabov, N. Volkova, A. Radjabov (Moscow, Russia)
A new application of photodynamic therapy for treatment of suppurative wounds and trophic ulcers

15.05-15.35 A. Stratonnikov, G. Meerovich, V. Loschenov (Moscow, Russia)
Photobleaching of photosensitizers in vivo during laser irradiation

15.35-16.00 Yu. Lozovik, S. Merkulova (Troitsk, Russia)
New method of laser therapy using fullerene

16.00-16.30 Coffee Break

Chairs: Z. Chen (USA) and R. Steiner (Germany) — Session 5.3

16.30-17.05 P. Gupta, S. Majumder (Indore, India)
Autofluorescence spectroscopy of human tissue for cancer diagnostics

17.05-17.35 G. Giubileo, L. De Dominicis, M. Giorgi, R. Pulvirenti (Rome, Italy), M. Snels (Tito Scalo, Italy)
A TDLAS system for the diagnosis of Helicobacter Pylori infection in humans

17.35-18.05 M. Frenz, B. Ott (Bern, Switzerland), N. Feltgen, F. Staubach, Th. Wesendahl, P. Janknecht (Freiberg, Germany), H. Weber (Bern, Switzerland)
In vivo Er:YAG laser ablation of retinal tissue

18.05-18.30 T. Fedorova (Moscow, Russia)
Optical assessment of microcirculation state in patients with chronic respiratory failure

Wednesday, July 19, 2000

Chairs: H. van den Bergh (Switzerland) and A. Priezzhev (Russia) — Session 5.4

11.00-11.35 Z. Chen (Irvine, USA)
Phase resolved optical coherence tomography and optical dopplertomography: functional imaging of tissue structure and physiology

11.35-12.05 A. Podoleanu, J. Rogers, D. Jackson (Canterbury, UK), S. Dunne (Toronto, Canada)
Compatibility of transversal and longitudinal OCT imaging of the tissue

12.05-12.35 V. Shuvalov, V. Petnikova, D. Chursin, I. Shutov (Moscow, Russia)
Diffusion optical tomography of scattering extensive objects: spatial resolution, scanning time, and fast reconstruction of hidden phantoms

12.35-13.00 V. Oshurko, Yu. Bykovsky, A. Karpiouk, A. Melekhov (Moscow, Russia)
Laser photoacoustic probe of absorber spatial organization

Thursday, July 20, 2000

Chairs: R. Ansari (USA) and A. Podoleanu (UK) **Session 5.5**

11.00-11.30 P. Corcuff (Aulnay-sous-bois, France)
Optical properties of the skin revisited by in vivo confocal microscopy

11.30-12.00 J. Lademann, H.-J. Weigmann (Berlin, Germany), H. Schaefer (Clichy, France), W. Sterry (Berlin, Germany)
Investigation of the penetration process of topically applied drugs and cosmetic products into the skin by spectroscopic measurements

12.00-12.30 N. Fomin (Minsk, Belarus), C. Fuentes, J.-B. Saulnier, J.-L. Tuhault (Chasseneuil, France)
Tissue blood flux monitoring by laser speckle photography

12.30-13.00 Q. Su, H. Wanare, R. Grobe (Illinois, USA)
Numerical solution of Maxwell's equations for biophysical systems

13.00-14.30 Lunch

Chairs: K. Kompa (Germany) and Q. Su (USA) **Session 5.6**

14.30-15.00 G. Klebanov (Moscow, Russia)
Free radical mechanisms of photobiological action of low power laser irradiation

15.00-15.30 V. Zuikov, V. Vorob'ev, A. Anisimov (Kazan, Russia)
Water - Ion transmembrane transfer in plant tissues under the effect of laser radiation

15.30-16.00 A. Anisimov, V. Vorob'ev, I. Semina, V. Zuikov (Kazan, Russia)
To the mechanism of biostimulation by laser irradiation: influence on membrane lipid component

16.00-16.30 P. Gupta, R. Kohli, A. Dubey (Indore, India)
Investigation on He-Ne laser irradiation effects on cells

16.30-17.00 Coffee Break

Chairs: S. Gonchukov (Russia) and H. Weber (Switzerland) **Session 5.7**

17.00-17.30 A. Priezzhev (Moscow, Russia)
Laser techniques for the assessment of blood structural and dynamic parameters in vitro and in vivo

17.30-18.00 V. Volnuhin (Moscow, Russia), S. Utz (Saratov, Russia), M. Kochetkov, A. Gonchukov (Moscow, Russia)
The modern approaches to application of low-intensive lasers in the treatment of various skin diseases

18.00-18.30 V. Oshurko, Yu. Bykovsky, A. Karpiouk, A. Melekhov (Moscow, Russia)
Laser photoacoustic detection of oil hydrocarbons in water emulsions

Dye-enhanced articular cartilage soldering

H.P. Weber, B.J. Züger, B. Ott, Th. Schaffner*, P. Mainil-Varlet*, M. Frenz

Institute of Applied Physics, University of Berne, Sidlerstrasse 5, CH-3012 Berne
Switzerland

phone: +41-31-6318943, fax: +41-31-6313765, E-mail: frenz@iap.unibe.ch

* Institute of Pathology, University of Berne,
Switzerland

Cartilage tissue is a tough and slippery material and possesses limited capacity for repair and self-regeneration when injured. On the other side, an increasing number of young people, especially sportsmen, suffer from cartilage injuries caused by sudden overstraining of their joints. This often results in scar formation which leads to permanent loss of structure and function. Up to now orthopedic surgery does not offer satisfying repair solutions. A common method used by many physicians is to mechanically reshape cartilage deformation using a shaver or nowadays by laser treatment. Both surgical techniques have in common that they reduce the thickness of the cartilage layer. Another possibility is the replacement of the affected tissue by healthy implants. The implantation of articular cartilage however demands good and strong connections during the long healing process which could be guaranteed by laser cartilage welding.

To study this new bonding technique, fresh cartilage was welded into previously placed cartilage defects by the use of Indocyanine green (ICG) enhanced albumin solder. The solder was irradiated through the cartilage implant with 808 nm laser light using a fiber. Optimal coagulation occurred when applying about 1.5 W for several seconds. Tensile strength and thermal damage of the weld were investigated. Conventional histologies for light microscopy (Masson-trichrome, Safranin-Orange and Alcian-blue staining) regularly performed to assess laser-induced tissue damage were compared with an efficient live/dead stain technique to point out chondrocyte viability of the laser-treated samples. The chondrocyte viability test was shown to be very sensitive to thermally induced damage and allows a quantification of the effective thermal damage after laser solder welding of articular cartilage.

Live/dead staining revealed a lateral thermal damage of up to 900 µm in depth at a radiant exposure of 180 J/cm^2 whereas conventional histologies showed up in maximum half of the extent found by the viability test. This means that although cell morphology looks normal under a light microscopy, cellular membranes are already compromised, allowing the ethidium homodimer-1 to stain nuclei. Out of the different conventional stainings used, Alcian-blue staining provided the most accurate histological information regarding the extent of tissue damage. The mechanical induced damage, generated by placing the cartilage defects, was found to be about 200 µm. Heat-bath investigations revealed a threshold temperature of 54°C for thermal damage of chondrocytes. Efficient cartilage bonding was obtained having tensile strengths of over 10 N/cm^2, which kept constant even after a 48 hours hydration period.

This study shows that it is possible to bond cartilage on cartilage using dye enhanced albumin solder and a diode laser at 808 nm for irradiation. In order to keep the thermal damage smaller than the mechanically induced damage the radiant exposure should not exceed 65 J/cm^2. This technique has a great potential to be used minimally invasive in arthroscopic surgery. In addition, this study showed that standard histology clearly underestimates the tissue damage after laser irradiation in comparison with the chondrocyte viability test.

Optimisation of laser epilation by simulation of the thermal laser effect

R. Steiner, D. Russ, A. Kienle
Institut für Lasertechnologien in der Medizin und Messtechnik an der Universität Ulm
W. Falkenstein, Carl Baasel Lasertechnik GmbH
Helmholtzstrasse 12, D-89081 Ulm, Germany
Phone: 49-731-142-910, Fax:142-942, E-mail: rudolf.steiner@ilm.uni-ulm.de

For hair removal lasers are used with wavelengths being selectively absorbed by melanin. As a consequence, laser reaction leads to temperature rise not only in melanin containing structures of the hair but also in the epidermis. Therefore, we simulated and studied the laser induced temperature rise in tissue for different laser wavelengths and pulse profiles. Modifying the beam parameters can improve the selectivity of the method.

Monte-Carlo Simulation was used for light absorption in thermal structures. Considering the tissue specific thermal qualities, the thermal diffusion in tissue was calculated by a finite difference method on the basis of a radial-symmetric tissue model.

As value for the biological reaction due to the temperature rise the arrhenius formalism was used to determine tissue necrosis depended on temperature and time of laser intervention. The simulation program allows to calculate the temperature distribution and thermal necrosis for different pulse-trains, energies and radiation geometry. Superficial cooling, of course, has an important influence and has been considered in the simulation.

The results of our simulations for different laser types show clearly differences in the thermal tissue reaction which allowed to optimise the treatment. Possibilities and limits of laser epilation can be estimated from these results. For example, the series of single laser pulses have some advantages compared to the reaction of a longer single pulse with the same energy.

NONSELECTIVE LASER THERMOLYSIS FOR THE BLOOD VESSELS ABLATION

Nikolai I. Tankovich
T&T Pharmaceuticals
9361 Stargaze Ave, San Diego, CA 92129, USA

The principal methods presently used for the skin blood vessel subsurface laser treatment involve the use the laser light which is selectively absorbed by the blood vessel hemoglobin in order to destroy the vessel by a very selective photothermolysis. The clinical use of lasers for the selective thermolysis for the last years showing a midium temporary efficacy for the facial telangiectasias and portwine stains with the blood vessels size not more than 0.2 mm; low or no efficacy for the spider leg veins and capillary hemangiomas with blood vessel size more than 0.2 mm. Attempts to increase fluence do not improve results.

My calculations, experiments and analysis of skin histology show the evidence and explanation why the selective photothermolysis does not work well for these vascular lesions. The laser radiation which wavelength matches the hemoglobin absorption coefficient reaches the blood vessel wall and started selectively heat a boundary layer of blood. Because of the high absorption of the light, the blood near the wall is coagulated forming a "shield" for the further light penetration into the blood vessel. The further laser irradiation heats the "shield" more but not the blood in the vessel. The size of the shield is not more than 100 – 200 micron. This is why the selective absorption is unable to heat through the whole blood vessel and it does not work effectively on blood vessels in size more than 200 micron.

The analysis of my study results suggests a use of the light with no or minimal hemoglobin absorption in order to heat blood through the vessel cross section, from wall to wall in a blood vessel to be coagulated. In order to heat a blood vessel to the temperature of the blood proteins coagulation by nonselective light the surface of the skin should be protected by effective cooling.

Experimental and clinical results of nonselective laser thermolysis of skin blood vessels are presented.

NOVEL LASER APPLICATIONS FOR RESHAPING AND TREATMENT OF DEFORMED AND DISEASED CARTILAGE.

E.Sobol, A.Omelchenko, A.Sviridov, V.Bagratashvili, N Vorobieva,
Institute of Laser and Information Technologies, Troitsk, Russia
Yu.Ovchinnikov, V.Svistushkin, Sechenov Medical Academy of Moscow
V.Baskov, Burdenko Neurosurgery Institute, Moscow
FAX: +7(095)3340342 E-mail: sobol@laser.ru

Many serous diseases of human body are related to deformed and diseased cartilage. An intensive study of new laser applications for medical treatment of cartilage have been curried out by various groups during last years. This paper will present the overview of previous data and also our recent results of studies in laser-induced stress relaxation and activation of regeneration processes in cartilaginous tissue as well as the results of animal in-vivo studies and clinical work. We used a Holmium laser (2.09 mcm) and a diode-pumped fiber laser (1.56 mcm) for laser treatment of spine dicks diseases (for rabbits) and for correction of deformed nasal septum (for humans).

It has been shown that the non-ablative laser irradiation allows: (1) to activate regeneration of healthy cartilage of hyaline type instead of destroyed nucleolus pulposus in spine dicks and (2) to replace a complicate conventional surgery on human nasal septum with a simple bloodless, painless, outpatients procedure which take a few minutes only and could be used, in particular, for children. The prospects of the new non-ablative laser applications in medicine, plastic surgery and cosmetology will be discussed.

Fluorescence endoscopy for the detection of early stage cancer in the lung and esophagus

Didier Goujon[1], Matthieu Zellweger[1], Alexandre Radu[2], Norbert Lange[1], Philippe Monnier[2], Georges Wagnières[1], Hubert van den Bergh[1]

[1] DGR-LPAS, Institute of Environmental Engineering, Swiss federal Institute of technology (EPFL), CH-1015 Lausanne (Switzerland)

[2] ENT Clinic, CHUV Hospital, CH-l011 Lausanne (Switzerland)

The modifications in the autofluorescence characteristics of the bronchial tissue is of crucial interest as a cancer diagnostic tool. An industrial prototype has been developed based on a previous spectroscopic study. More than 20 patients have been investigated. The false positive rate can be decreased by processing the images and using decisional functions. The resulting positive predictive value is around 70%.

A new application of photodynamic therapy for treatment of suppurative wounds and trophic ulcers

E.Ph.Stranadko, U.M.Koraboyev, M.V.Riabov, N.N.Volkova, A.A.Radjabov
State Research Center for Laser Medicine, Ministry of Public Health of Russia.
121165, Moscow, Studentcheskaya st., 40, e-mail: geinic@cityline.ru, phone/fax: 249-39-05, phone:187-46-29, fax: 181-24-52;

Successful application of photodynamic therapy (PDT) for treatment of malignant tumors led to the use of this promising technique in a number of non-tumoral diseases. We attempted to use PDT for treatment of suppurative diseases of soft tissues.

A series of experimental studies on lethal photosensitization of microorganisms have been performed. Species of bacteria most common met in suppurative wounds were taken into investigation (Staphylococcus aureus, Staphylococcus epidermidis, Proteus mirabilis, Esherichia coli, Pseudomonas aeruginosa). Sulphonated aluminum phthalocyanine (Photosense™, produced in Russia by NIOPIC State Research Center) in concentrations from 25 to 500 μg/ml was used as a photosensitizer for pre-irradiation incubation. A diode lamp with broad-band wavelength of emission (range 600 - 700 nm) and a solid-state laser Poljus-2 (yttrium aluminate) with wavelength 670 nm were used as sources of light. The studies showed high bactericidal and bacteriostatic action of PDT. Straight correlation between concentration of photosensitizer and bactericidal action of PDT was observed at the same energy density (24 J/cm^2).

At the Clinical Department of the State Research Center for Laser Medicine PDT was used in 50 patients for treatment of suppurative wounds (14), trophic ulcers caused by chronic phlebic deficiency of lower extremities (9), atherosclerosis of the arteries of lower extremities (13), diabetic angiopathy (9), and bedsores (5).

We used 20-24-hour applications of 0.05% Photosense water solution on the wound surface before laser irradiation. One day after PDT wound surface cleared. Active granulations appeared in 3 - 4 days. In 9 patients with large skin defects autodermoplasty with good results was performed in 7 - 9 days after PDT. In comparison to traditional treatment the use of PDT in combination with plastic surgery lead to faster wound healing and rehabilitation of the patients..

PHOTOBLEACHING OF PHOTOSENSITIZERS IN VIVO DURING LASER IRRADIATION

Alexander A. Stratonnikov, Gennady A. Meerovich, and Victor B. Loschenov
Laser Biospectroscopy Lab, General Physics Institute, 38, Vavilov street, Moscow, 117942, Russia.
Email: biospec@glasnet.ru

The photobleaching of photosensitizers (PS) applied for photodynamic therapy (PDT) has been widely studied in vitro and in vivo including clinical cases. This phenomenon is very important for PDT dosimetry. For example the high bleaching rate of protoporphyrin IX (PPIX) suggests the corresponding tactics of light irradiation with low light fluence rate and multiple light sessions. It has been also suggested that PS photobleaching might serve as an implicit factor in PDT dosimetry. The kinetic behavior of photobleaching curves may give information about the mechanism of PDT and makes it possible to evaluate PDT efficiency in different conditions. For example, the second order bleaching kinetics assumes the involvement of oxygen in PDT reactions, or the fluorescence outburning observed for some PS suggests the primary PS localization in lysosomes followed by its relocalization into cytoplasm under influence of light. This knowledge may be used to evaluate PS photo physical properties and to develop appropriate PDT tactics for achieving efficient treatment results.
This paper deals with studying photobleaching kinetics of two different PS applied for clinical trials in Russia at present time: ALA induced PPIX and sulphonated aluminum phthalocyanines (Photosense). First, a simple photobleaching model will be given taking into account the influence of tissue optics on data interpretation. The results of PPIX photobleaching kinetics observed in human skin and mice liver will be presented and explained by the proposed model. The experimental data for fluorescence decay of ALA induced PPIX during light irradiation are fitted fairly well into this model.

As opposed to PPIX the photobleaching behavior for sulphonated aluminum phthalocyanines is rather complicated to be fitted by proposed mathematical model. The fluorescence outburning and residual fluorescence for sulphonated aluminum phthalocyanines have been observed. It has been shown that fluorescence maximum correlates with blood oxygen saturation decrease induced by PDT effect.

AUTOFLUORESCENCE SPECTROSCOPY OF HUMAN TISSUE FOR CANCER DIAGNOSIS

P. K. Gupta and S. K. Majumder,
Biomedical Applications Section
Centre for Advanced Technology
Indore, India, 452 013

Telephone: 091-731-488432; Fax: 091-731-488430/481525; e-mail: pkgupta@cat.ernet.in

ABSTRACT

There exists considerable current interest on the use of laser induced fluorescence (LIF) from native human tissues for sensitive, in-situ, near real time diagnosis of cancer. The in-vitro studies carried out at CAT, on tissues resected at surgery or biopsy from patients with cancer of oral cavity, breast or uterus could discriminate malignant human tissues from benign tumour and normal with sensitivity and specificity of ~ 90% in general and up to 100% in favourable cases. The results of excitation/ emission, synchronous luminescence and time resolved studies carried out at CAT on breast and oral cavity tissues suggest a significant variation in the concentration of the fluorophores in the different tissue types. In particular, the studies reveal that while concentration of NADH is higher in malignant breast tissues compared to benign tumor and normal breast tissues the reverse is true for tissues from oral cavity where NADH concentration is higher in normal oral tissues. These results have also been confirmed by enzymatic measurements of NADH concentration in malignant and normal tissues from breast and oral cavity. The differences in fluorophore concentration inferred from spectroscopic studies qualitatively explain the observed spectral differences in the autofluorescence spectra of the oral and breast tissues.

In-vivo studies on patients with cancer of oral cavity or of uterine cervix have also been initiated using the LIF based prototype systems developed at CAT. A pilot study involving 25 patients with histopathologically confirmed cancer of oral cavity has yielded satisfactory discrimination results.

In the talk we shall provide an overview of the use of autofluorescence spectroscopy of human tissues for cancer diagnosis with emphasis on the results obtained at CAT.

NEW METHOD OF LASER THERAPY USING FULLERENE

Yu.E.Lozovik , S.P.Merkulova
Institute of Spectroscopy, 142190 Moscow region, Troitsk,
Russia; e-mail: lozovik@isan.troitsk.ru
Fax:+7 095 334 08 81

Possible usage of new carbon clusters (fullerenes, carbon nanotubes etc.) in laser therapy is discussed.
Photophysics of fullerenes and singlet oxygen is analized.

The lowest triplet excited state of fullerene C60 and C70 molecules is almost resonant with the first singlet excited state of oxygen molecule. The efficiency of pumping of triplet state of fullerene is essentially higher than that for the singlet state of oxygen. Besides one can excite efficiently siglet state of fullerene which fast relaxate to lower triplet state. So singlet oxygen playing essential role in blood therapy can be effectively produced by two stages:
1) laser pumping of fullerene (initially transporting it in appropriate location),
2) resonance transfer (with almost 100% efficiency) of the excitation from fullerene to $^1\Sigma_g$ state of oxygen molecule.

3) fast relaxation of $^1\Sigma_g$ state of oxygen molecule to lower singlet state $^1\Delta_g$ of (singlet) oxygen.

Posible laser induced processes in fullerenes and carbon nanotubes are discussed.

A TDLAS system for the diagnosis of Helicobacter Pylori infection in humans.

G. Giubileo, L. De Dominicis, M.Giorgi, R.Pulvirenti*
ENEA C.R. Frascati, Via E. Fermi 45, 00044 Frascati, Roma, Italia
Tel. +39 06 9400 5768 - Fax +39 06 9400 5400 - E-mail giubileo@frascati.enea.it

M.Snels
Istituto per Materiali Speciali (C.N.R.),Zona Industriale
85050 Tito Scalo

The bacterium H.pylori is believed to cause the peptic ulcera disease. H.pylori infection in human stomach can be detected through a CO_2 isotopic ratio measure in expired breath.
In the present work the Tunable Diode Laser Absorption Spectroscopy optical system (TDLAS) devoted to $^{13}CO_2/^{12}CO_2$ ratio measurement realised in ENEA Molecular Spectroscopy Laboratory is described. The experimental apparatus consists of a IR tunable diode laser operating at the liquid nitrogen temperature and emitting single mode radiation around 2305cm^{-1} where only strong absorption lines of CO_2 are present. The well isolated P(35) line for $^{12}CO_2$ and R(32) line for $^{13}CO_2$ have been chosen for measuring the isotopic ratio.
The human breath is collected in a balloon and then transferred into a Herriot multipass cell (2m of optical path) whose exit window is coupled to the entrance slit of a monochromator. Each revealed absorption spectrum is recorded by an IR detector and stored in a PC. Main experimental efforts have been devoted in making the system friendly-usable. The whole experimental system is controlled through a GPIB interface and the acquisition of the desired spectra has been completely automated by computer programs. Data processing and calculation of the isotopic ratio are performed on-line by a specially developed software. Comparison between theoretical and experimental spectra has been performed through the Hitran PC simulation software.
Calibrating procedure and experimental results both on reference mixture and human breath are reported and discussed.

In vivo Er:YAG laser ablation of retinal tissue

M. Frenz, B. Ott, N. Feltgen*, F. Staubach*, Th. Wesendahl*, P. Janknecht*, H.P. Weber

Institute of Applied Physics, University of Berne, Sidlerstrasse 5, CH-3012 Berne
Switzerland

phone: +41-31-6318943, fax: +41-31-6313765, E-mail: frenz@iap.unibe.ch

* Department of Ophthalmology, Albert-Ludwig-Universität Freiburg
Germany

Proliferative retinopathy, ocular inflammation or non-proliferative vascular disorders are ocular diseases that have the potential to develop membranes on the inner surface of the retina (epiretinal membranes). These membranes often exert traction on the underlying retina causing visual impairment or tractional detachment of the macula. Currently, the common method of treatment is to mechanically remove these membranes from the retinal surface by engaging the edge and peeling it off with a micro-forceps which includes the risk of mechanical damage to the retina.

The Er:YAG laser has been shown to produce precise tissue ablation because its radiation at a wavelength of λ = 2.94 µm is highly absorbed by water. A drawback of this strong absorption, however, is the generation of violent water vapor bubbles combined with the generation of strong pressure transients if tissue ablation is performed in a non-transmitting aqueous media. This mechanical stress may lead to retina detachment.

The goal of this study therefore was to systematically evaluate the effects of Er:YAG laser radiation on pig retina in vitro (enucleated eyes) and in vivo utilizing a transmitting perfluorodecaline (PFDL)/retina interphase.

The output of a free-running Er:YAG laser operating at 2.94 µm was coupled into a ZrF_4 optical fiber (length 2 m, core diameter 350 µm) with an endoprobe tip (quartz) of 1 mm in diameter. The laser could be tuned to emit variable pulse energies ranging from 1.25 mJ to 83.0 mJ resulting in a radiant exposure at the fiber tip of 0.995 J/cm^2 to 10.57 J/cm^2. Epiretinal membranes were generated in pig eyes by vitrectomy, retinotomy and cryocoagulation of the retina and subsequent injection of PDGF (platelet derived growth factor). Following the removal of the vitreous body by a pars plana vitrectomy, the epiretinal membranes were ablated under general anesthesia using radiant exposures from 0,6 to 2,05 J/cm^2 per pulse. Half of the laser-treated eyes were enucleated directly after laser treatment or 2 weeks after surgery. All eyes were examined histologically with the masson´s trichrome method to assess retina alterations.

The in vitro studies revealed that tissue ablation linearly increased with radiant exposures from 3.2 ± 3.7 µm at 1 J/cm^2 up to 40.9 ± 12.9 µm at 10 J/cm^2. Thermal tissue changes extended 70 ± 10 µm vertically into the retina and 25 ± 5 µm horizontally. Distortion of outer photoreceptor segments was noticed when the retina was exposed to radiant exposures of 3 J/cm^2 or higher. The in vivo studies confirmed these findings. Histological comparison of laser-treated eyes with eyes treated by conventional microforceps techniques revealed that undesired retina damage was in all cases much less after laser treatment.

The results showed that by using a perfluorocarbon liquid that exhibits a low absorption of IR-radiation, it is possible to precisely ablate epiretinal membranes in vivo without damage of deeper retinal layers.

OPTICAL ASSESSMENT OF MICROCIRCULATION STATE IN PATIENTS WITH CHRONIC RESPIRATORY FAILURE

Tatiana A. Fedorova
Moscow Medical Academy
Gagarinsky pereulok, 24-29, Moscow, 121002 Russia.
Phone: (095) 241-92-99; fax: 945-47-32

Being a frequent complication of chronic obstructive pulmonary disease (COPD), respiratory failure leads to a loss of capacity for work and invalidity in many of these patients. In the development of progressive gas exchange abnormalities in this pathology, different microcirculatory disorders connected with blood rheology and vascular rearrangements play the major role.

In present investigation a number of hemorheological indices and the condition of vessels in the microcirculatory bed of 120 patients with COPD and different degrees of the respiratory failure are analysed.

Photometric method to detect platelets and erythrocytes aggregation and biochemical methods to investigate the plasmatic factors of hemostasis were used; the condition of microcirculatory vessels in transparent argentated preparations of visceral pleura and in eye-conjunctiva was evaluated by means of biomicroscopy.

Significant hemorheological abnormalities were found in all patients with COPD. An increase of the degree of respiratory failure characterised by more frequent and severe hemorheological disorders: enhanced aggregation of platelets, spontaneous aggregation and disturbed process of disaggregation. Changes in platelets correlated with changes in haemostasis of 87% of patients with COPD: they had an increased erythrocyte aggregation and elevated blood viscosity.

Patients with the most severe disease, which resulted in the respiratory failure and right-sided heart failuar formed a special group. One third part of these patients demonstrated a decrease of functional activity of platelets with the absence of disaggregation, combined with changes in plasmatic indices of haemostasis, which confirms the presence of chronic disseminated intravascular microcoagulation of blood.

Prevailing process of intravascular aggregation of blood cells and microthrombosis were confirmed by the results of biomicroscopy of eye-conjunctiva and morphological examination of visceral pleura.

Vascular rebuilding of microcirculatory bed during the increase of the degree of respiratory failure was studied. A close correlation between the degree of vascular changes and the severity of hemorheologocal disorders was demonstrated.

Phase Resolved Optical Coherence Tomography and Optical Doppler Tomography: Functional Imaging of Tissue Structure and Physiology

Zhongping Chen

Beckman Laser Institute, University of California Irvine, Irvine, CA 92612
Phone: 949-824-1247 Fax: 949-824-8413 E-mail: zchen@bli.uci.edu

A noninvasive optical technique is developed for imaging in vivo tissue structure and hemodynamics with high spatial resolution (10 μm). The technique, phase resolved optical Doppler tomography, combines Doppler velocimetry with optical coherence tomography to imaging in vivo tissue structure and blood flow velocity with high spatial resolution (10 μm) and high velocity sensitivity (10 μm/s). The phase resolved technique decouples spatial resolution and velocity sensitivity in flow images and increases imaging speed by more than two orders of magnitude without compromising either spatial resolution and velocity sensitivity. The exceptionally high velocity sensitivity and high spatial resolution of phase resolved OCT/ODT allow us to imaging microvasculature and hemodynamics in human skin for the first time. The noninvasive nature of this technique have many applications in the clinical management of patients in whom imaging tissue structure and monitoring blood flow dynamics is essential. Applications of this technique to imaging changes in tissue structure and hemodynamics following pharmacological intervention and photodynamic therapy, screening vasoactive drug, evaluating efficacy of laser treatment of port wine stain patient, and mapping cortical hemodynamics for brain research will be demonstrated. Potential applications of this technique for mapping three-dimensional tumor microvasculature for tumor diagnosis and angiogenesis studies will be discussed.

Compatibility of Transversal and Longitudinal OCT Imaging of the Tissue

Adrian Gh. Podoleanu, John A. Rogers, David A. Jackson

Applied Optics Group, School of Physical Sciences, University of Kent, Canterbury, CT2 7NR, UK, Fax: +44 1227 827558; e-mail A.G.H.Podoleanu@ukc.ac.uk

Shane Dunne [1]Ophthalmic Technologies, Inc., Toronto, Canada

The majority of the reports on optical coherence tomography (OCT) [1] relate to the production of longitudinal OCT slices in the tissue, i.e. images containing the optical axis. This way of "cutting out" the tissue was stimulated mainly by a technical reason: when moving the mirror in the reference path, not only the depth is scanned, but a carrier is also produced for the reflectivity signal from the tissue. The carrier frequency is the Doppler shift produced by the longitudinal scanner itself (moving along the axis of the system, Z, to explore the tissue in depth).

En-face imaging [2] is also desirable, offering in real time, slices in the tissue at orientations perpendicular to the optic axis. For studies of the eye, this is extremely important. Confocal scanning ophthalmoscopes (SLO) are transversal imagers. A large data base of SLO images exist and the expertise in recognizing ailments of the eye could be easily transferred to the OCT technology. This may also be valid for skin, where transversal patterns of collagen or anisotropy may present interest for diagnostic. Confocal images of the skin have already been produced.

If en-face (transversal) images at a fixed depth are necessary, in this case a path imbalance modulator is needed in order to create a carrier for the image bandwidth. We have shown that the transversal scanner [3] (X or Y-scanning device) itself can be used, in a way similar to the utilisation of the longitudinal scanner. However, differences exist in terms of the signal bandwidth and frequency carrier created by longitudinally scanning and by transversally scanning the object. Therefore, compatibility issues arise between the two OCT images, produced by different scanning procedures. The compatibility criteria are analyzed, both hardware and software in relation to the following parameters: signal bandwidth, pixel size along each of the two axes, and depending the case, dynamic range and penetration depth.

Hardware compatibility refers to the parameters of the same oriented slice, as for instance (X,Z) when hardware obtained by transversal OCT or by longitudinal OCT imaging.

Software compatibility refers to the compatibility of the (X,Z) slice obtained by hardware in the longitudinal OCT regime with the same oriented (X,Z) slice but software generated from the stack of transversal (X,Y) images collected at different depths by a transversally operated OCT system.

Using a versatile OCT system, we generate both transversal as well as longitudinal OCT images from the retina and skin in vivo. We compare the hardware parameters of images in the two regimes and show that the transversally generated OCT images of longitudinal slices have similar quality with the longitudinally generated longitudinal OCT images (despite the fact that the frequency of the carrier generated in the transversal OCT imaging, varies across the target). We evaluate the compromise between scanning speed and transversal pixel resolution when using the carrier created by the transversal scanner alone.

Collecting a stack of transversal OCT images for a depth of 1 mm (in the retina and in the skin) we then demonstrate by software differently oriented longitudinal cuts. Then, using the same system, longitudinal images are collected. Comparison of these images for the eye involves the quantification of the amount of movement along different direction, which may find application in practice.

Finally, 3D images from retina and skin are demonstrated.

1. A. F. Fercher, "Optical coherence tomography", J. Biomed. Opt., 1(2), pp. 157-173, 1996.
2. A. Gh. Podoleanu, M. Seeger, G. M. Dobre, D. J. Webb, D. A. Jackson and F. Fitzke "Transversal and longitudinal images from the retina of the living eye using low coherence reflectometry", J. Biomed Optics, 3(1), pp. 12-20, 1998.

Diffusion optical tomography of scattering extensive objects: spatial resolution, scanning time, and fast reconstruction of hidden phantoms

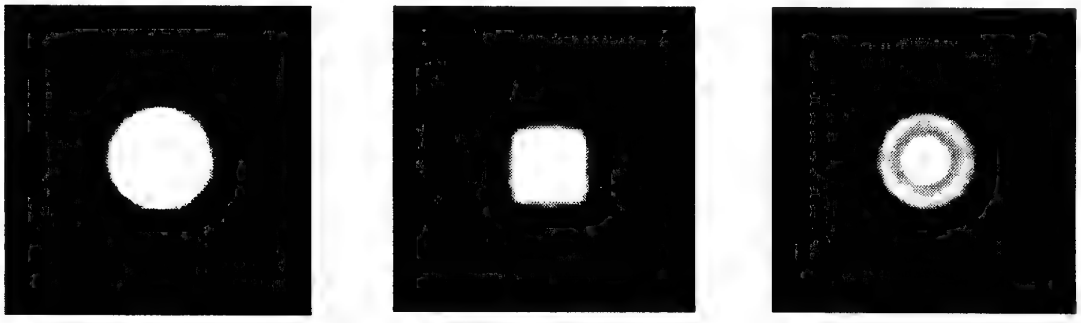
V.V. Shuvalov, V.M. Petnikova, D.A. Chursin, I.V. Shutov

M.V. Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119899, Russia

Phone: +7(095)9395035, Fax: +7(095)9393113, E-Mail: vsh@vsh.phys.msu.su

Main defects of present optical tomography systems are connected with a comparatively small depth of diagnostics and rather slow operation of reconstruction algorithms that are used to solve so-called "direct" and "inverse" problems. We present our recent results obtained in experimental approbation of diffusion optical tomography as a visualization technique for imaging of small (linear size down to 5 mm) absorbing and scattering insertions ("phantoms") inside extensive (linear size up to 15 cm) weakly-absorbing and highly-scattering (absorbing and scattering constants about 0.005 - 0.015 and 1.4 mm^{-1} correspondingly) model objects. A special modification of reconstruction algorithm, that needs in only about 3 minutes to reconstruct such insertion's hidden image, will be described. The modification has been developed on the basis of results of our computer simulation (the Monte-Carlo technique) of corresponding 2D and 3D problems and of the data of performed experimental research. A substantial difference between 2D and 3D cases will be discussed.

In our experiments, an IR CW diode laser (the wavelength about 808 nm) with output power less than 15 mW has been used. After passing through an extensive model object (a small-sized fat-in-water emulsion with an absorber) simulating optical characteristics of a biological tissue, an output radiation has been detected by a special high-sensitive registration system (Hamamatsu R-636-10 photomultiplier) operating in a photon counting regime. To reconstruct a 5-mm phantom image hidden by multiple scattering processes, a 2D matrix, composed of 32×32 projections, has been used. With a minimal signal to noise ratio s/n = 1, the maximal time for one-projection measurement about 0.3 - 0.8 sec has been reached.



Zoomed reconstructed images of small highly-absorbing phantoms with round (the left picture) and square (the middle picture) cross-sections inside the extensive model object. A specific hallo around a reconstructed image of a small highly-scattering phantom is shown in the right picture.

LASER PHOTOACOUSTIC PROBE OF ABSORBER SPATIAL ORGANIZATION

V.B.Oshurko, Yu.A.Bykovsky, A.B.Karpiouk, A.P. Melekhov

Moscow Engineering Physics Institute, 115409,

Kashirskoye 31, dept. 25 , Moscow, Russia

Phone/fax : (095) 323 -9066, e-mail: avb @ phsearch.msk.ru

Fourier transform in photoacoustics was traditionally used for absorption spectra enhancement.(fourier-transform infrared photoacoustics) As to pulsed photoacoustics, in usual method the only first acoustic pressure oscillation may be used for absorption analysis, because of many disturbing factors (e.g. sound reflections interference). However, as it was found in present work , acoustic Fourier spectrum of total signal (after ~ ns pulsed excitation) may bring an information about spatial organizitaion of absorbing specimen.

In experiments acoustic Fourier spectera from especially prepared 100 ppms oil emulsion and low-concentration dye (salt) solution were compared. Both dye solution and oil emulsion have been made to provide the same (1) total absorption coefficient and (2) thermodynamic parameters. Because of low consentration , all these these parameters (except absorption) differs from that water < 1 %.

It was found that there is a significant difference between emulsion and solution in higher frequency region of Fourier spectra (> 1 MHz). As it was shown, the signal at these freqencies is proportional to oil concentration in emulsion. Microscopic observations have shown that the size of oil droplet in emulsion may be less than 1 micron when this spectral difference is still present.

It has also been found that this effect demonstrates non-linear increase with the raise of laser beam intensity.

Theoretical model has been developed to explain this phenomenon.The model based on different heating/cooling dynamics of droplet and solution element. It was found that different colling rates could provide the difference in acoustic frequences. If temperature dynamics is taken into account, it becomes clear why photoacoustic signal may be sensitive to submicron spatial structure of absorber (less than even laser wavelength).

LPHYS'2000

Optical properties of the skin revisited by in vivo confocal microscopy.

Pierre Corcuff - L'Oréal, Laboratoires de Recherche Avancée, Aulnay-sous-bois, France.

Phone : 33 1 48 68 96 34 ; E-mail : pcorcuff@recherche.loreal.com

The way by which the light penetrates through the skin tissue remains a complex phenomenon due to the multiple stratification and to the biochemical composition of epidermal and dermal layers. It has been established that skin optics respect the rules of absorption, reflection and scattering. Absorption coefficients have been experimentally determined and mainly depend on the content of melanin in the epidermis and the blood perfusion (hemoglobin) in the dermis. They rapidly decrease at longer wavelength. Reflection corresponds to the index mismatch at various interfaces i.e. air/skin surface, water/protein. Reduced scattering concerns the heterogeneous organization of the dermis, the anisotropy of the collagen network and follows the Raleigh limit exhibiting the well-known λ^{-4} behavior.

In such a context, in vivo confocal microscopy uses reflected signal to form an image the contrast of which is improved by strong reflection and by a limited lack of photons by absorption and scattering. A new generation of confocal laser microscope, designed to image the human skin in vivo, improves the resolution, contrast and spectroscopic facilities as compared to the previous Tandem Scanning Microscope (TSM) prototype(1). The new device has been built with a Oz module (Noran) equipped with the skin contact device (2), assuming a perfect stability of skin images in the horizontal plane. The Z displacement of the objective lens, mounted directly on the Oz module, is assumed by a piezo motor with a course of 90 mm. Moreover, the Oz module has been suspended on articulated arms to reach any part of the human body. The power of the Argon/Krypton laser source has been limited to 2mW to secure safety and provides three visible wavelength : 488, 568 and 647 nm. The facility of instantly checking wavelength during in depth exploration of the skin optimises the resolution and contrast of images as compared to the white light used in the TSM. Optical sections are digitized (512x512x8 bit) at video rate, providing easy and fast measurements of the thickness of epidermal layers. The Silicon Graphics workstation generates a transparent volume of living human skin in less than 10 minutes.

Consequently, better image quality of the stratum corneum is obtained in the blue region with unexpected details of corneocytes . The living epidermis can be resolved in the green region and the papillary dermis comprising the vascular network is advantageously observed with the red light. The rapid lack of photons due to the strong scattering of the dermis greatly limits in depth exploration to about 250 µm beneath the skin surface. At this depth the only red laser line delivers understandable information and it has been possible to observe for the first time the lymphatic flow in the dermis.

Melanin provides a strong reflection of the basal keratinocytes instead of the absorption expected. The explanation can be the shape and the size of melanosomes. Ultrastructural morphology and 3D reconstruction of the melanin cap in basal keratinocytes confirmed the behaviour of melanosomes acting as a myriad of nanomirrors thus reflecting the light.

This powerful and convivial new design for imaging the in vivo human skin opens up new promise in skin research.

Biography :

(1) Morphometry of human epidermis *in vivo* by real-time confocal microscopy.
P.Corcuff, C.Bertrand, J.L.Lévêque. *Arch Dermatol Res* 285:475-481;1993.

(2) *In vivo* confocal microscopy of human skin: a new design for cosmetology and dermatology.
P.Corcuff, G.Gonnord, G.E.Piérard, J.L.Lévêque. *Scanning* 18(3):351-355;1996.

Investigation of the penetration process of topically applied drugs and cosmetic products into the skin by spectroscopic measurements

J. Lademann[1], H.-J. Weigmann[1], H. Schaefer[2] W. Sterry[1],

(1) Humboldt University, Charité, Center of experimental and applied cutaneous physiology, Berlin Germany
(2) L`ORÉAL, Research, Centre Charles Zviak, F-9 2583 Clichy Cedex, France

The tape stripping method is a well-known analytical method to determine penetration properties. This method has the disadvantage that the amount of sunscreen components, e.g. microparticles, can be determined only in relation to the tape strip number. A correlation of the obtained results to the relative thickness of the horny layer is not possible. These problems can be solved combining the method of tape stripping with spectroscopic measurements.
The UV/VIS spectroscopic measurements were made with a double beam spectrophotometer, Lambda 20, Perkin Elmer, modified to obtain a rectangular beam diameter of 10 times 10 mm^2. The absorbance measured at 430 nm was taken as the measure for the mass of the corneocyte aggregates placed on the individual tape.
The optical absorbance and the weight of corneocyte aggregates were compared as parameters for the determination of the mass of the horny layer particles fixed to the individual tapes. It was proven that the absorbance in the visible range is better suited than the weight to quantify the amount of corneocyte aggregates removed by a single strip.
The results were confirmed by laser scanning microscopy measurements.
This new developed combined method allows the determination of the actual position of the sunscreen components in the stratum corneum. It was used in the present report to analyze the penetration properties of drugs and cosmetic products into the skin.

Tissue blood flux monitoring by laser speckle photography

N.Fomin*,**, C.Fuentes**, J.-B.Saulnier**, and J.-L.Tuhault**

* Heat and Mass Transfer Institute, Minsk, 220072, Belarus
e-mail: fomin@hmti.ac.by, tel: +375 284 13 53; fax: +375 232 25 13

**Laboratoire d'Etude Thermiques - UMR CNRS 6608 - ENSMA, BP 40109, Futuroscope 86961, Chasseneuil cedex, France;
e-mail: fomine@let.ensma.fr; tel: +33 (0)5 49 49 81 00, fax: +33(0) 5 49 49 81 01

A map of the blood micro circulation activity in living tissues is of considerable importance for many diagnostic purposes. The skin microcirculation fulfills the function of thermal regulation of the body [1]. Present paper deals with the blood microcirculation monitoring using CCD recording of the sequences of the dynamic bio-speckle patterns produced when a tissue under study is illuminated with a laser beam with subsequent cross-correlation analysis of these patterns.

Bio-speckle pattern is observed when a living semi-transparent tissue under study is illuminated by a laser light. The visible laser light penetrates into the human skin on the deepness of about 200-1000 μm and multiple scattered by the red blood cells (RBCs) flowing inside the smallest candelabra capillaries as well as by the surrounding tissue. Experimental installation for the blood flux microcirculation monitoring is similar to speckle photography scheme [2]. The light beam from a pulsed or CW laser illuminates a fingertip and is scattered back by moving RBCs. The scattered light is collected by lens to a screen for observation where a speckle pattern is formed. This speckle pattern is digitally recorded by CCD camera in to PC memory. Time sequences of such speckle patterns with different time interval between successive frames (from 0.5*ms* to 40*ms.)* are recorded. Subsequent cross-correlation analysis of these frames allows determining the local speckle intensity variations due to scatterers movement during the time interval between successive frames.

Thus the time-space cross-correlation analysis of the temporal evaluation of bio-speckle patterns is shown to be a means of tissue blood microcirculation flow visualization. Digital processing of bio-speckle patterns records yields 2D maps exhibiting the blood flow temporal and spatial variations. This might be used for bio-medical diagnostic purposes for detecting e.g., micro-scale deviation from the normal case.

References

1. Dittmar A. et al. Estimation of skin blood from the measurement of thermal conductivity // Innovation et Technologie en Biologie et Medicine: Special Issue, 1991.Vol.12. N.1.P.121-137.
2. Fomin N. Speckle Photography for Fluid Mechanics Measurements, Springer Verlag, Berlin, 1998

Abstract for LPHYS'2000, Bordeaux, July 17-21, 2000.

Numerical solution of Maxwell's equations for biophysical systems

Q. Su, H. Wanare and R. Grobe

Intense Laser Physics Theory Unit
and Department of Physics
Illinois State University
Normal, IL 61790-4560

309-438-5392 (phone)
309-438-5413 (fax)
qcsu@ilstu.edu

Abstract

We have developed a spectral-domain method in combination with a split-operator technique to solve numerically the time dependent Maxwell equations for highly scattering media such as biological tissues. In contrast to all previous methods this approach takes into account the evanescent waves and phase information of the diagnostic laser beam. We can now simulate the laser-tissue interaction on a much smaller length scale at which other methods such as those based on the diffusion approximation are known to become quite unreliable. We also apply this technique to study the tunnelling signal of evanescent wave occurring due to frustrated total internal reflection and the propagation of a light pulse through an inhomogeneous medium consisting of multiple random scatterers.

* Supported by grants from the NSF PHY-9970490, Research Corporation PHY-CC4089 and Illinois State's URG.

[1] W. Harshawardhan, Q. Su and R. Grobe, Phys. Rev. E, submitted.

Free radical mechanisms of photobiological action of low power laser irradiation.

G.I. Klebanov
Department of Biophysics, Russian State Medical University
1 Ostrovitjanova st., Moscow, 117869, Russia University
Tel: +7 (095) 434-1174, E-mail: klebanov@fbm.msu.ru

Low-power laser irradiation (LPLI) is widely used in clinics in two main directions - in photodynamic therapy of tumors (PDT) and in the treatment of a number of inlammatic diseases, laser therapy (LT). PDT of tumors is based on the photoinduction of free radical reactions, finally, affection of tumor cells. LT mechanisms are less definite and probable reactions are widely hypothesized. Application of LPLI in clinics induces the following pathophysiological reactions - dilation of microcapillars, blood rheology changes and cell proliferation. These mechanisms restore oxygen and drug delivery to ischemised tissues and organs. Moreover, proliferation of cells accelerated wound recovery. Blood leukocytes are major participants of all these processes. Recently, we've formulated a concept of free radical action of LPLI. This concept states that laser radiation chromophores are endogenuous porphirins, absorbing light and act as a photosensitizers. The targets of laser irradiation are leukocytes and lipoproteins, containing porphirins. Porphirins, absorbing laser light induce photochemical free radical reactions, that induce lipid peroxidation in leukocyte membranes and lipoproteins. Lipid peroxidation induces Ca^{2+} permeability and cell priming that is realised in the increasing of cell activity and enchanced production of biologically active compounds (nitric oxide, superoxide, hypochlorite etc.). Some of these species posess bactericidal action and can affect blood microcirculation. For instance, nitric oxide is known as a precursor of so called Endothelium Derived Relaxing Factor (EDRF), factor relaxing the vasculature. Leukocyte priming induces increased cytokine production, cell proliferation and endogenuous bypasses creation. Thus, leukocyte priming, induces vasodilation, vasogenesis and accelerates reperfusion and oxygen delivery to the ischemised organ as well as drugs, that previously didn't reach the organ due to hemostasis. All these pathophysiological mechanisms support the therapeutical action of LPLI in the treatment of inflammatory processes. In this paper we present experimental evidence for the main statements of the mentioned above free radical hypothesis of LPLI action, based on leukocyte priming.

"Water - Ion Transmembrane Transfer in Plant Tissues Under the Effect of Laser Radiation"

V. Zuikov., V. Vorob'ev+., A. Anisimov+

Kazan Physical-Technical Institute, 420029, 10/7, Sibirsky tract, Russian Academy of Sciences, Kazan, Russia
+Kazan Institute of Biochemistry and Biophysics, Russian Academy of Sciences, Kazan, Russia

Biostimulating effect of low intensity laser radiation is widely used in medicine. The problem is to determine the primary targets and the mechanisms of the effect of laser radiation (LR) on cells.
According to a number of investigators, one of the targets for LR is cell plasmalemma (the membrane effect).
The comparison of the decrease of spin-spin relaxation time, increase of water effective self-diffusion coefficient along with the data on the acceleration of ion penetration into cells testifies the increase of water transmembrane transfer velocity under the effect of laser radiation. The mechanism of plasmalemma permeability for water and ions increase might be the discussed in a number of papers effect of singlet oxygen, which might result in permeability increase via intensifying the process of lipid peroxidation, and resulting in the decrease of membrane lipid bilayer viscosity.
The increase of the velocity of the chloroplast rotational movement in the cells remote from the radiated one, together with the data on the decrease of the amount of unfrozen water (the latter is due to the removal of overcooling by effective stirring of protoplasm) testify in favour of the thrinning of unstirred by-membrane Nernst layers, which results in the decrease of their diffusional resistance to water and ion transfer.

TO THE MECHANISM OF BIOSTIMULATION BY LASER IRRADIATION : INFLUENCE ON MEMBRANE LIPID COMPONENT

A.Anisimov, V. Vorob'ev, I. Semina and V. Zuikov*

Kazan Institute of Biochemistry and Biophysics, Russian Academy of Sciences,

P.O.Box 30, 420503 Kazan, Russia

Tel.: (8432) 38-32-03, fax: (8432) 38-75-77, e-mail: anisimov@sci.kcn.ru

*Kazan Physical–Technical Institute, Russian Academy of Sciences

Widespread concepts on the development of laser biological stimulation (LBS) process (generation of singlet oxygen – free radical state) lack clarity in understanding of further events, but the final mechanism of LBS is seen to be in regulatory changes of cell membrane permeability.

For elucidation of the possibility of direct influence of laser irradiation (LI) on membranes and identification of a membrane component sensitive to LI, experiments on model lipid membranes prepared from phosphatidyl choline in the from of 20 % water suspension of multilayer membrane bubbles – polyliposomes were carried out. By H^1 NMR method effective water diffusion coefficients were measured in lipolsme suspension before and after irradiation by infrared laser generation AGNIS – L01 (wave – length 850 nm, power 2.4 mWt) with irradiation dose changes as parameter.

The increase of the fraction and attenuation decrement of the slowly decaying component is registered in multicomponent diffusional decay of water magnetization signal in liposome suspension after LI. The experimental data are interpreted in terms of changes of rate of water diffusion exchange through polyliposome lipid membranes under LI. In its turn, the mechanism of such a response of membranes is connected with modulation of peroxide oxidation of lipids. The concluding possible scheme of biostimulation is: generation of singlet oxygen - initiation of free radical states – modulation of peroxid oxidation of membrane lipid component - membrane complex permeability changes – activation of reparation processes.

INVESTIGATIONS ON He-Ne LASER IRRADIATION EFFECTS ON CELLS

P. K. Gupta, R. Kohli and A. Dubey
Biomedical Applications Section
Centre for Advanced Technology
Indore, India, 452 013

Telephone: 091-731-488432; Fax: 091-731-488430/481525; e-mail: pkgupta@cat.ernet.in

ABSTRACT

He-Ne laser (632.8 nm) pre-irradiation was observed to induce protection against UVC radiation in wild type *E. coli* strain, K12AB1157. The magnitude of protection was found to depend on He-Ne laser irradiance, exposure time and the period of incubation between the He-Ne laser exposure and subsequent UVC irradiation. Mechanistic studies suggest that the induced protection may be mediated via singlet oxygen. The details of the mechanism involved are however not understood. In this respect it may be useful to investigate the possible effect of He-Ne laser irradiation on the different DNA repair processes. Studies have therefore been carried out on the effect of He-Ne laser pre-irradiation on UVC damage in an UV sensitive mutant (*uvrA*-) *E. coli* strain KY706/pPL-1. This strain contains a plasmid *pPL-1*, which has the promoter region of the *phr* gene and *phr-LacZ* fusion gene, because of which induction of photolyase gene expression (*phr*) can be easily monitored. He-Ne laser pre-irradiation was observed to lead to both, a protection against UVC exposure and an induction of *phr* in this strain. Both the effects were found to have similar dependence on the preirradiation dose, irradiance and the period of incubation between preirradiation and UVC exposure. This would suggest that the induction of *phr* has a role to play in the observed protection. Further, mechanistic studies suggest the involvement of singlet oxygen in the induction of *phr*. This observation is in conformity with other reports where oxidative stress has been shown to lead to induction of *phr*. However, how induction of *phr* reduces UVC induced damage in absence of photoreactivating light is still not clear. It may perhaps be a part of the adaptive response and may be accompanied with the induction of other genes as well. This needs further investigations.

He-Ne laser pre-irradiation has also been observed to lead to protection against UVA induced DNA damage in cultured human B lymphoblast cells (NC-37). The results of these experiments suggest that He-Ne laser pre-irradiation leads to a lower initial DNA damage and has no effect on DNA damage repair kinetics.

The details of these studies will be presented in this report.

Laser techniques for the assessment of blood structural and dynamic parameters *in vitro* and *in vivo*

Alexander V. Priezzhev
Physics Department and International Laser Center
M.V. Lomonosov Moscow State University
Vorobiovy Gory 119899 Moscow, Russia
Tel.: (7 095) 939- 2612; Fax: (7 095) 939-3113
E-mail: avp@lbp.ilc.msu.su, avp@tools.ru

Abstract

Blood is a complex fluid exhibiting variable structural, rheological, and dynamic properties and composition. It permanently and dynamically interacts with other tissues of a live organism and thus reflects its functioning and pathological changes. This provides challenge to further study blood and correlate its newly assessed properties with the state and functioning of the organism.

Recent success in the study of laser interaction with biological tissues in general and with blood in particular enables researchers to develop new optical techniques for noninvasive quantitative assessment and monitoring of blood parameters *in vitro* and *in vivo*. In comparison with conventional methods currently used in clinics the newly developed optical techniques are usually cheaper, faster, more compact and informative, which better suits the demands of researchers, clinicians and population for implementation of more efficient early diagnosis of many diseases.

Static light scattering from whole blood samples *in vitro* can be efficiently applied for the quantitative measurement of aggregation and disaggregation properties of red blood cells. The latter exhibit dramatic changes in case of many diseases like cardio-vascular, autoimmune, diabetes, etc., and are related to severe aggravations in the state of a patient as hemorheological disorders. Recent developments in the design of compact laser Doppler blood flowmeters, microscopes, and specklometers, as well as diffusing wave spectrometers and capillaroscopes enable highly accurate dynamic *in vivo* measurements of blood in single vessels and microcirculatory layer. These measurements are highly important for quantitative estimates of hemorheological disorders and oxygen consumption-related tumor growth and destruction, etc. Video- and computer enhanced diffractometry provides new information on deformability of red blood cells in shear flow, which in combination with multiple scattering spectroscopy allows to conclude about orientation of the shear stress-deformed blood cells in bulk flow that determines the blood flow parameters but so far can not be calculated theoretically. Application of microchip laser technologies opens new possibilities for raising efficiencies of such widely used diagnostic techniques as flow cytometry, microscopy and spectroscopy.

The paper will provide an overview of the state-of-the-art of the research in these directions and will discuss trends for future developments.

The modern approaches to application of low-intensive lasers in the treatment of various skin diseases

V.A. Volnuhin[1], S.R. Utz[2], M. A. Kochetkov[1], A.S. Gonchukov[1]

[1]*Central Research Institute for Skin and Venereological Diseases*
3 Korolenko street, 107076, Moscow, Russia
tel 964-3989, fax 964-4458, vvoln@caravan.ru
[2]*Saratov Rural Hygiene Institute*
135 Chernyshevskogo, 410071, Saratov, Russia

The main results and reachings on usage low-intensive laser irradiation (LLI) in dermatological practice are parsed. The effects of laser therapy of the most known and wide-spread skin diseases (atopic dermatitis, eczema, herpes simplex and herpes zoster, vasculites, psoriatic arthritis etc.) are surveyed. The indications and contraindications to assignment of laser therapy in dermatology, and main side effects are represented. The methodical approaches and ways of delivery LLI to a skin are discussed. The perspectives of new therapeutic laser technologies - transcutaneous irradiation of blood and laser photochemotherapy - are justified.

LASER PHOTOACOUSTIC TECHNIQUE FOR WATER CONTROL

V.B.Oshurko, Yu.A.Bykovsky, A.B.Karpiouk, A.P. Melekhov

Moscow Engineering Physics Institute

115409, Kashirskoye 31, dept. 25 , Moscow, Russia

Phone / fax : (095) 323 -9066

e-mail: avb @ phsearch.msk.ru

Traditional photoacoustic water control is based on photoexcitation of specific absorber and acoustic response analysis. As it was found in present work, acoustic Fourier spectrum (after pulsed laser excitation) in higher-frequencies domain depends on the presence of non-absorbing solutes. The mechanism of this phenomenon is discussed in report. It gives a new possibility of water quality or impurities control. It has been shown that the combination of this technique with neural network methods of recognition allows one to recognize a producer of water-based commercial products.

Investigation of the aggregation and disaggregation properties of erythrocytes by light scattering measurements

Juergen Lademann, Hans-Juergen Weigmann, Wolfram Sterry,
University Hospital Charité, Dermatological Clinic, Berlin Germany
phone: +49-30-2802-3578, fax: +49-30-2802-8415,
email: juergen.lademann@charite.de

Gerhard Müller
Laser- and Medical Technology GmbH Berlin, Germany

Alexander V. Priezzhev
Physics Department and International Laser Center
of the Lomonosov State University Moscow, Russia

Nicolai N. Firsov
Medico-Biological Department of the Russian
State Medical University Moscow, Russia

Abstract text:

Different analytical methods are used for blood diagnostics on clinical conditions. The aggregation and disaggregation behavior of erythrocytes reflects pathological states of the human body. In the present paper the aggregation and disaggregation process of human blood samples is investigated by remission measurements. The whole blood samples were analyzed using a rotating coaxial cylinder system in combination with a special method for data processing. The erythrocyte aggregates were destroyed completely without injuring the cell membranes by shear forces arising during the cylinder rotation. The time behavior of the remission signal during the aggregation process was investigated. The disaggregation process was characterized by the dependence of the remission signal intensity on different applied shear rates.
The influence of the optical and blood parameters on the remission signal was analyzed to determine standardized measuring conditions.
The correlation of the aggregation and disaggregation measurements to routine sedimentation measurements is described.
A correlation of the aggregation and disaggregation behavior to different diseases was found. In the present paper the analytical method was used for the diagnosis of diabetes and thrombosis diseases.